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Beyond Algorithms: Toward a Normative Theory of Automated Regulation

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BEYOND ALGORITHMS: TOWARD A NORMATIVE THEORY OF AUTOMATED REGULATION

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Abstract: The proliferation of artificial intelligence in our daily lives has spawned a burgeoning literature on the dawn of dehumanized, algorithmic governance. Remarkably, the scholarly discourse overwhelmingly fails to acknowledge that automated, non-human governance has long been a reality. For more than a century, policy-makers have relied on regulations that automatically adjust to changing circumstances, without the need for human intervention. This Article surveys the track record of self-adjusting governance mechanisms to propose a normative theory of automated regulation. Effective policy-making frequently requires anticipation of future developments, from technology innovation to geopolitical change. Self-adjusting regulation offers an insurance policy against the well-documented inaccuracies of even the most expert forecasts, reducing the need for costly and time-consuming administrative proceedings. Careful analysis of empirical evidence, existing literature, and precedent reveals that the benefits of regulatory automation extend well beyond mitigating regulatory inertia. From a political economy perspective, automated regulation can accommodate a wide range of competing beliefs and assumptions about the future to serve as a catalyst for more consensual policy-making. Public choice theory suggests that the same innate diversity of potential outcomes makes regulatory automation a natural antidote to the domination of special interests in the policy-making process. Today's automated regulations rely on relatively simplistic algebra, a far cry from the multivariate calculus behind smart algorithms. Harnessing the advanced mathematics and greater predictive powers of artificial intelligence could provide a significant upgrade for the next generation of automated regulation. Any gains in mathematical sophistication, however, will likely come at a cost if the widespread scholarly skepticism toward algorithmic governance is any indication of future backlash and litigation. Policy-makers should consider carefully whether their objectives may be served as well, if not better, through more simplistic, but well-established methods of regulatory automation.

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INTRODUCTION

Artificial intelligence is all the rage these days, dominating the public discourse from investor earnings calls to legal scholarship.[1] Between 2017 and 2019, twenty-two of the top twenty-five law reviews in the United States published one or more pieces on smart algorithms, machine learning, and other forms of artificial intelligence.[2] Remarkably, the burgeoning literature on artificial intelligence and the future of algorithmic governance almost universally fails to acknowledge that non-human, automated governance has long been a reality. For more than a century, policy-makers have relied on regulations that automatically adjust to changing circumstances in order to mitigate the negative consequences flowing from flawed forecasts and regulatory inertia.

Policy-makers have no crystal ball. Yet, they are frequently required to anticipate the future as they adopt new, or amend existing, laws and regulations.[3] The stakes are high. Laws and regulations crafted on the basis of false assumptions about the future have, at best, no real-life impact and, at worst, a negative impact on public health, economic development, and other important goods. Few areas are more prone to these pitfalls than energy law and policy, the case study serving as the empirical backdrop for this Article's normative inquiry into the merits of regulatory automation.[4]

Power plants, transmission lines, and other energy assets take years, if not decades, to build and require vast amounts of capital investment. Once deployed, many of these assets have a useful life of forty years or more.[5] Add to

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[1] *See, e.g.*, Andrew Barnes, *2018 Trends That Will Remain All the Rage in 2019*, ENTREPRENEUR: ASIA PACIFIC (Feb. 5, 2019), https://www.entrepreneur.com/article/327479 [https://perma.cc/NH8A-HYS4] (listing artificial intelligence as a top trend for entrepreneurs across the globe); Kim Hart, *Why AI Is All the Rage Right Now*, AXIOS (Mar. 1, 2017), https://www.axios.com/why-ai-is-all-the-rage-right-now-1513300691-b75d9693-cb04-466b-89e1-5976707d124a.html [https://perma.cc/CKT6-PJJC] (noting the dramatic increase in companies discussing artificial intelligence during earnings calls).

[2] This data is based on search of title and abstract across the 2017–2019 volumes of the flagship law reviews of the top twenty-five law schools per *U.S. News and World Report*. *See 2021 Best Law Schools*, U.S. NEWS & WORLD REP. (2020), https://www.usnews.com/best-graduate-schools/top-law-schools/law-rankings [https://web.archive.org/web/20201128215119/https://www.usnews.com/best-graduate-schools/top-law-schools/law-rankings] (search log on file with author).

[3] *See, e.g.*, Daniel A. Farber, *Uncertainty*, 99 GEO. L.J. 901, 901 (2011) ("Many of the pressing policy issues facing us today require confronting the unknown and making difficult choices in the face of limited information."); Justin R. Pidot, *Governance and Uncertainty*, 37 CARDOZO L. REV. 113, 116 (2015) ("Lawmakers must act, even recognizing the limits of their knowledge, or else remain forever paralyzed.").

[4] The terms regulatory automation and automated regulation are used synonymously throughout this Article.

[5] *See, e.g.*, ASCE: AM. SOC'Y OF CIV. ENG'RS, 2017 INFRASTRUCTURE REPORT CARD: ENERGY (2017), https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Energy-Final.pdf [https://perma.cc/RQ92-JARE] (noting the fifty-year life expectancy of transmission and distribution lines).

that an unprecedented rate of disruptive innovations, from hydraulic fracturing to solar power, to electric vehicles, and it becomes clear why energy policy-makers were among the first to experiment with regulations that automatically adjust to changing circumstances.[6]

Perhaps the best-known example of such automated regulation is the fuel-price adjustment clause used to automatically adapt a regulated utility's retail rates to changes in the price of coal, natural gas, and other fuel inputs.[7] Other, more complex, mechanisms tie the level of financial incentives for emerging clean energy technologies to the observed pace of deployment. When deployment falls short of desired levels, incentives automatically increase and, conversely, decrease to slow down faster-than-expected deployment. These and other manifestations of regulatory automation often serve as insurance for policy-makers concerned with crafting policies based on assumptions about the future that reality may prove inaccurate.

Unlike its heir-apparent algorithmic governance, automated regulation has received surprisingly little scholarly attention to date.[8] Historically, policy-makers have used regulatory automation primarily to counter the negative effects that lengthy administrative processes would have on regulated industries. Existing scholarship and judicial precedent debate the efficiency of self-adjusting regulations and their fit within the administrative state, but they fail to offer a holistic assessment of the virtues and vices of regulatory automation. This Article seeks to close that gap, assessing the political economy of automated regulation, its implications for public choice theory, and the proper relationship between self-adjusting governance instruments and competitive markets, among others. What emerges from this analysis is a first conceptualization of the normative theory of regulatory automation. From a policy perspective, this normative assessment suggests that, properly designed and implemented, self-adjusting regulations offer significant benefits to policy-makers and stakeholders, extending well beyond their traditionally emphasized function as insurance against forecast errors.

This is not another article on algorithmic governance. I merely reference it as one point along the broad spectrum of dehumanized, automated governance options. If anything, this Article cautions policy-makers to give more serious consideration to traditional methods of regulatory automation before

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[6] *See infra* notes 38–40, 45–46 and accompanying text.

[7] *See, e.g.*, Joe H. Foy, *Cost Adjustment in Utility Rate Schedules*, 13 VAND. L. REV. 663, 664–65 (1960); Richard J. Pierce, *Reconsidering the Roles of Regulation and Competition in the Natural Gas Industry*, 97 HARV. L. REV. 345, 350 (1983); R.S. Trigg, *Escalator Clauses in Public Utility Rate Schedules*, 106 U. PA. L. REV. 964, 964, 967, 972 (1958).

[8] *See, e.g.*, Pidot, *supra* note 3, at 168 (expressing surprise that automated regulation "has received so little attention").

rushing into algorithmic governance, thereby burdening themselves and their constituents with the many unresolved questions surrounding algorithmic due process, privacy, and other concerns.[9]

This Article proceeds in four Parts. Part I illustrates the appeal of self-adjusting regulatory regimes as insurance against forecasting errors in a fast-changing world, for energy policy and beyond.[10] A comparison of global and domestic energy forecasts with historic data going back thirty years reveals the woeful inaccuracy of the expert predictions that inform policy-making around the world. The impact of these forecasting errors is exacerbated by the capital intensity and longevity of most energy assets, which combine to raise the risk that poorly informed policy choices end up creating suboptimal, yet long-lasting, path dependencies.

Part II introduces a representative sampling of self-adjusting regulatory instruments in use today and proposes a coherent typology using the choice of independent variable as the point of distinction.[11] Historically, policy-makers have mostly relied on the passage of time as catalyst for regulatory adaptation, such as through a sunset clause or another time-related trigger for self-executing change. More recently, policy-makers have tethered automatic regulatory adjustments to more dynamic indicators like the pace of technology deployment and other market metrics.

Combining empiricism with qualitative analysis, Part III explores past, present, and future challenges and opportunities to develop a normative theory of regulatory automation.[12] Critics and proponents alike claim to have efficiency arguments on their side. Closer scrutiny of the scholarly debate and empirical evidence suggests that, properly designed and implemented in the appropriate context, the benefits of automated regulation are likely to outweigh attendant costs. Opponents of regulatory automation frequently challenge its compatibility with the procedural mandates of the administrative state. Yet, more than one court has dismissed concerns about notice and hearing requirements as well as alleged shifts in the burden of proof, among other procedural

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[9] *See infra* note 242 and accompanying text. *See generally* Danielle Keats Citron, *Technological Due Process*, 85 WASH. U. L. REV. 1249 (2008) (proposing a new approach to protecting due process that addresses advancements in automated decision-making systems in individual adjudication and rulemaking procedures); Danielle Keats Citron & Frank Pasquale, *The Scored Society: Due Process for Automated Predictions*, 89 WASH. L. REV. 1 (2014) (discussing the need for enhanced due process protections amidst the increased use of artificial intelligence in credit reporting systems); Cary Coglianese & David Lehr, *Transparency and Algorithmic Governance*, 71 ADMIN. L. REV. 1 (2019) (asserting that machine-learning algorithms are understandable to the public and that algorithmic governance need not necessarily pose a threat to fair and transparent government).

[10] *See infra* Part I.

[11] *See infra* Part II.

[12] *See infra* Part III.

objections. From a political economy perspective, regulatory automation promises to foster more consensual policy-making as the ex ante consideration of eventualities allows for greater accommodation of competing conceptions of the future. Based on the tenets of public choice theory, finally, regulating on autopilot has the potential to reduce the influence that special interests exert upon the regulatory process. Part III concludes by offering policy-makers guidance as to the proper scope of application for automated regulation and its relationship with competitive markets.

Part IV situates automated regulation vis-à-vis algorithmic governance powered by artificial intelligence.[13] Both represent but two points, among many, along a continuum of options for adaptive regulation and dehumanized governance. Today's self-adjusting regulations are both less and more developed than algorithmic governance. In terms of technical sophistication and mathematical complexity, deep-learning algorithms are lightyears ahead of the relatively simple algebraic functions historically used to deliver automated regulatory adaptation. These automated regulations, however, do resemble their more sophisticated algorithmic progeny insofar, as both seek to complement, if not altogether replace, human decision-making with automated actions. Unlike the emerging but as-yet largely theoretical concept of algorithmic governance,[14] dehumanized governance through self-adjusting regulation has long been a reality. Over a century's worth of empirical evidence offers a rich track record for policy-makers and scholars to mine for insights that can help inform the future of algorithmic and other non-human decision-making and governance.

I. The Need for Insurance Against Forecast Errors

Predicting the future is easy; the hard part is getting it right, or so the saying goes. History is, indeed, replete with predictions of the future that have turned out to be horribly wrong. Consider the following assessment of the long-term appeal of television, offered by 20th Century Fox studio head Darryl Zanuck in 1946: "[T]elevision won't be able to hold on to any market it captures after the first six months. . . . People will soon get tired of staring at a plywood box every night."[15] More than seventy years later, television remains a fixture in the daily routine of most households, with the average American

[13] *See infra* Part IV.

[14] *See, e.g.*, Coglianese & Lehr, *supra* note 9, at 7 ("Today, most governmental applications of machine learning are not determinative of final actions.").

[15] *Worst Tech Predictions of All Time: Darryl Zanuck, 1946*, The Telegraph (June 29, 2016), https://www.telegraph.co.uk/technology/0/worst-tech-predictions-of-all-time/darryl-zanuck-in-1964/ [https://perma.cc/Y3PW-VRDS].

adult watching over five hours of television daily.[16] Sure, televised content may be moving away from traditional networks and into online streaming formats, but consumers do not seem to tire of staring at "plywood boxes" and their progeny, including flat-screen TVs, tablets, and smartphones.

The following verdict, from a 1966 article in Time Magazine, on the viability of remote shopping has proven similarly off the mark, and not just for its sexist undertone: "remote shopping, while entirely feasible, will flop—because women like to get out of the house, like to handle the merchandise, like to be able to change their minds."[17] Half a century later, online shopping is pushing more and more traditional retailers out of business.[18] Led by Amazon, Alibaba, eBay, and others, the e-commerce retail industry accounted for $3.5 trillion in sales globally in 2019.[19]

Forecasts from industry insiders, even when offered for significantly shorter timeframes, have not fared much better, as demonstrated by the 2007 skepticism of Microsoft's then-CEO Steve Ballmer regarding the market appeal of Apple's iPhone: "There's no chance that the iPhone is going to get any significant market share."[20] Within one year of its release, Apple's gadget went

[16] *See, e.g.*, John Koblin, *How Much Do We Love TV? Let Us Count the Ways*, N.Y. TIMES (June 30, 2016), https://www.nytimes.com/2016/07/01/business/media/nielsen-survey-media-viewing.html [https://perma.cc/8LJU-NF2A].

[17] *The Futurists: Looking Toward A.D. 2000*, Essay, TIME, Feb. 25, 1966, at 28, 29, http://content.time.com/time/subscriber/article/0,33009,835128-5,00.html [https://perma.cc/K6Y4-PERE].

[18] One of the most prominent early victims of the online retail revolution was Borders, a forty-year-old chain of bookstores. *See* Julie Bosman & Michael J. de la Merced, *Borders Files for Bankruptcy*, N.Y. TIMES (Feb. 16, 2011), https://dealbook.nytimes.com/2011/02/16/borders-files-for-bankruptcy [https://perma.cc/6BJT-HURV]. The recent bankruptcy of brick-and-mortar retailer Mattress Firm suggests that even bulky, harder-to-deliver merchandise that was traditionally subject to intense in-store testing and comparison, is no longer safe from the online retail revolution. *See* Nathan Bomey, *Mattress Firm Files for Chapter 11 Bankruptcy Protection, Will Close up to 700 Stores*, USA TODAY (Oct. 5, 2018), https://www.usatoday.com/story/money/2018/10/05/mattress-firm-chapter-11-bankruptcy/1532218002/ [https://perma.cc/66EF-RTHK]. The COVID-19 pandemic has further accelerated this trend, with online retail sales more than doubling between the spring of 2019 and 2020. *See* Louis Columbus, *How COVID-19 Is Transforming E-commerce*, FORBES (Apr. 28, 2020), https://www.forbes.com/sites/louiscolumbus/2020/04/28/how-covid-19-is-transforming-e-commerce/#44bdc7763544 [https://perma.cc/74W7-6V9J].

[19] *See* Daniela Coppola, *Global Retail E-commerce Sales 2015–2023*, STATISTA (Nov. 26, 2020), https://www.statista.com/statistics/534123/e-commerce-share-of-retail-sales-worldwide/ [https://perma.cc/Z6KB-28M9]. In the wake of the COVID-19 pandemic, online retail numbers are likely to be significantly higher for 2020.

[20] David Lieberman, *CEO Forum: Microsoft's Ballmer Having a "Great Time,"* USA TODAY (Apr. 29, 2007), https://usatoday30.usatoday.com/money/companies/management/2007-04-29-ballmer-ceo-forum-usat_N.htm [https://perma.cc/DUT7-SXP2].

on to capture nearly 13% of the global smartphone market, vastly exceeding Ballmer's prediction of 2% to 3% of the market share.[21]

Even a bona fide genius, operating within their domain of expertise, can be dismally wrong in predicting the future, as evidenced by Albert Einstein's 1932 assessment of the technological viability of nuclear power: "[T]here is not the slightest indication that [nuclear] energy will ever be obtainable. That would mean that the atom would have to be shattered at will."[22] A mere decade later, a team of scientists led by Italian physicist Enrico Fermi achieved the first self-sustaining nuclear reaction, turning the alleged pipe dream of nuclear fission into technological reality.[23] Today, nuclear power accounts for nearly one-fifth of all electricity generation in the United States.[24]

If even industry insiders and certified geniuses are this far off the mark in their predictions, how can we possibly expect policy-makers to anticipate what the future holds? The good news is that, at least in the energy domain, hordes of analysts have devoted themselves to forecasting future trends and developments, often on an annual basis. The not-so-good news is that their track record is less than reassuring. In fact, a comparison of past predictions with historical reality suggests that highly trained analysts using vast data sets and state-of-the-art modeling techniques fare little better than a fortune teller reading tea leaves.[25]

In some instances, forecasts may be guided not only by the data available, but also by the issuing entity's vested interests and place in the energy economy. This would explain why the energy outlook publications periodically released by oil companies, such as ExxonMobil, British Petroleum, and Royal Dutch Shell, have come under attack for consistently underestimating future growth in solar, wind, and other renewables that threaten the fossil fuel industry's business interests.[26] ExxonMobil's 2005 Energy Outlook, for example,

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[21] *See* Robert Palmer, *iPhone Triples Market Share as of Q3 2008*, ENGADGET (Dec. 4, 2008), https://www.engadget.com/2008/12/04/iphone-triples-market-share-in-q3-2008/ [https://perma.cc/Q4V5-F5WK].

[22] Victor Navasky, *Tomorrow Never Knows*, N.Y. TIMES MAG., Sept. 29, 1996, at 216, https://www.nytimes.com/1996/09/29/magazine/tomorrow-never-knows.html [https://perma.cc/BYR4-HDG4].

[23] *See, e.g.*, U.S. DEP'T OF ENERGY, THE HISTORY OF NUCLEAR ENERGY 6–9, https://www.energy.gov/sites/prod/files/The%20History%20of%20Nuclear%20Energy_0.pdf [https://perma.cc/4Q39-NXWX].

[24] *See* U.S. ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 2019 WITH PROJECTIONS TO 2050, at 21 (2019), https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf [https://perma.cc/4XDM-DJ44].

[25] *See infra* notes 32–35, 41–43 and accompanying text.

[26] *See, e.g.*, GREG MUTTITT, OIL CHANGE INT'L & GREENPEACE, FORECASTING FAILURE: WHY INVESTORS SHOULD TREAT OIL COMPANY ENERGY FORECASTS WITH CAUTION 8 (2017), http://priceofoil.org/content/uploads/2017/03/Forecasting-Failure-oil-company-outlooks.pdf [https://perma.cc/SB58-7TYX] (questioning the plausibility and accuracy of oil companies' forecast of future energy trends).

projected that wind and solar would account for one percent of global energy generation by 2030. In reality, wind and solar reached this share in 2012, eighteen years ahead of ExxonMobil's predicted schedule.[27] Critics point out that, despite being presented as objective expert assessments, many company forecasts are, in fact, more advocacy than analysis.[28]

Luckily for policy-makers, there is no shortage of publicly funded energy analysts, such as those responsible for the energy outlooks released by the International Energy Agency and the U.S. Energy Information Administration (EIA). Going back to a mandate included in the Department of Energy Organization Act of 1977,[29] the EIA's Annual Energy Outlook (AEO) projects future supply, demand, and resources for energy and electricity in the United States.[30] As the federal government's chief energy forecast, AEO projections are widely relied upon by industry and policy-makers alike.[31] So how accurate are these projections? If the large number of peer-reviewed publications devoted to forecast errors in the AEOs is any indication, the EIA's projections leave much to be desired in terms of accuracy.[32] Indeed, several commentators warn of systematic bias in the EIA's projections.[33] Others decry that, based on a comparison of past forecasts with historical data, "far less confidence should have been placed on past AEO forecasts than was claimed by the forecasters."[34] The same commentators go on to caution that "it is prudent to apply the same scepticism to current and future AEO forecasts."[35]

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[27] *Id.* at 2.

[28] *Id.* at 15.

[29] Department of Energy Organization Act of 1977, Pub. L. No. 95-91, 91 Stat. 565 (codified as amended at 42 U.S.C. §§ 7101–7352).

[30] *See, e.g.*, U.S. ENERGY INFO. ADMIN., *supra* note 24, at 4.

[31] *See* Alexander Q. Gilbert & Benjamin K. Sovacool, *Looking the Wrong Way: Bias, Renewable Electricity, and Energy Modelling in the United States*, 94 ENERGY 533, 534 (2016).

[32] *See, e.g.*, Maximilian Auffhammer, *The Rationality of EIA Forecasts Under Symmetric and Asymmetric Loss*, 29 RES. & ENERGY ECON. 102, 119–20 (2007); Carolyn Fischer et al., *Understanding Errors in EIA Projections of Energy Demand*, 31 RES. & ENERGY ECON. 198, 199 (2009); Gilbert & Sovacool, *supra* note 31, at 540; George M. Lady, *Evaluating Long Term Forecasts*, 32 ENERGY ECON. 450, 450–51 (2010); Alexander I. Shlyakhter et al., *Quantifying the Credibility of Energy Projections from Trends in Past Data: The US Energy Sector*, 22 ENERGY POL'Y 119, 124–25 (1994). Additionally, the International Energy Agency's (IEA) projections are met with similar levels of criticism in the literature. *See, e.g.*, Luisa F. Cabeza et al., *Comparison of Past Projections of Global and Regional Primary and Final Energy Consumption with Historical Data*, 82 RENEWABLE & SUSTAINABLE ENERGY REVS. 681, 682–83 (2018); Hua Liao et al., *Why Did the Historical Energy Forecasting Succeed or Fail?: A Case Study on IEA's Projection*, 107 TECH. FORECASTING & SOC. CHANGE 90, 95 (2016).

[33] *See, e.g.*, Fischer et al., *supra* note 32, at 199–200; Gilbert & Sovacool, *supra* note 31, at 540–41.

[34] Shlyakhter et al., *supra* note 32, at 125.

[35] *Id.*

It is to the EIA's credit that the agency issues an annual retrospective, comparing its past AEO forecasts dating back to 1994 to actual data.[36] Unfortunately, the AEO Retrospective is limited to some twenty high-level data points, and for example, omits data specific to renewables and other emerging technologies. Still, two trends emerge: first, the EIA does a better job of forecasting energy consumption than other indicators, likely because consumption is fairly inelastic and tends to change more slowly;[37] second, supply-side data reveal the agency's general inability to predict technological innovation and disruption. The most poignant example of this dynamic is the EIA's complete failure to anticipate the transformative effect that directional drilling and hydraulic fracturing would have on the U.S. energy economy.[38] Failing to account for the oil-and-gas boom facilitated by fracking in shale plays across the country, the EIA had erroneously expected the United States to remain a net importer of fossil fuels for decades to come. As a result, the agency's projections on natural gas imports missed the mark by nearly three hundred percent.[39] Such dramatic forecast errors have implications far beyond the circles of a few disgruntled academics. Relying on EIA projections, for example, industry majors commissioned dozens of terminals, at a cost of billions of dollars, to import liquefied natural gas via supertankers from the Middle East and elsewhere, only to abandon most of these projects when hydraulic fracturing obviated the need for foreign natural gas.[40]

The EIA's forecasting fares even worse when turning from fossil fuels to renewables. In its 2000 AEO reference case scenario, for instance, the agency projected that by 2020 non-hydroelectric renewables would account for 3.1%

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[36] *See, e.g.*, U.S. ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK (AEO) RETROSPECTIVE REVIEW: EVALUATION OF AEO2018 AND PREVIOUS REFERENCE CASE PROJECTIONS 1, 2 (2018), https://www.eia.gov/outlooks/aeo/retrospective/pdf/retrospective.pdf [https://perma.cc/TTY9-PAUX].

[37] *Id.* at 2.

[38] For a thoughtful introduction to the regulatory challenges and transformational effects of hydraulic fracturing, see John M. Golden & Hannah J. Wiseman, *The Fracking Revolution: Shale Gas as a Case Study in Innovation Policy*, 64 EMORY L.J. 955, 983–1000 (2015); David B. Spence, *Federalism, Regulatory Lags, and the Political Economy of Energy Production*, 161 U. PA. L. REV. 431, 477–506 (2013).

[39] *See* U.S. ENERGY INFO. ADMIN., *supra* note 36, at 3.

[40] In the mid-2000s, analysts (falsely) anticipated that imported liquefied natural gas (LNG) could account for more than one-fifth of U.S. consumption. *See* CONG. RSCH. SERV., LIQUEFIED NATURAL GAS (LNG) IN U.S. ENERGY POLICY: INFRASTRUCTURE AND MARKET ISSUES 5 (2006), https://www.everycrsreport.com/files/20060131_RL32386_bc179dca9098af9ba02579d24d0bbe6f87410203.pdf [https://perma.cc/H9C6-CQ8A]. For a snapshot of the general exodus from LNG import terminals following the advent of hydraulic fracturing, see U.S. DEP'T OF ENERGY, NORTH AMERICA LNG IMPORT TERMINALS, https://www.energy.gov/sites/prod/files/2013/04/f0/LNG%20Import%20%26%20Export%20Terminal%20Maps%2012-18-2012.pdf [https://perma.cc/B5C3-KWLW] (diagraming the evolution of North American LNG import terminals).

of the nation's electricity generation.[41] A more optimistic "high renewables case" raised this share to a daring 4.6%.[42] As of year-end 2018, two years before the close of the EIA's projection period, non-hydro renewables had already vastly exceeded even the most optimistic AEO forecast, fueling 10.8% of U.S. electricity generation.[43] The agency's skepticism of renewables is best illustrated by its expectation that "[l]ess than 400 megawatts of renewable generating capacity is expected to be built after 2012."[44] In reality, nearly 16,000 megawatts of new wind and solar capacity were added in 2015 alone,[45] forty times the capacity additions the EIA had projected for *all* non-hydro renewables over a period of *eight* years. Once again, the EIA's woefully inaccurate projections create serious real-world problems, particularly for grid operators tasked with maintaining the electricity system's delicate balance between demand and supply to ensure reliable electric service. Successful integration of a growing share of weather-dependent solar- and wind-powered generators, whose output varies by season and time of day, requires advance planning to ensure necessary upgrades to physical infrastructure and market rules, among others.[46] The recent proliferation of renewable generation infrastructure took even industry insiders relying on the EIA's conservative projections by surprise, making the transition to a low-carbon U.S. electricity sector more complicated than necessary.

In light of such a dismal forecasting track record, policy-makers could be forgiven for choosing to ignore expert projections altogether. To do so, however, would obscure the fact that policy-makers themselves are often making the

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[41] *See* U.S. ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 2000 WITH PROJECTIONS TO 2020, at 72 (1999), https://www.hsdl.org/?abstract&did=15936 [https://perma.cc/7496-AY32].

[42] *Id.*

[43] For the data underlying this calculation, see U.S. ENERGY INFO. ADMIN., APRIL 2019 MONTHLY ENERGY REVIEW 125, https://www.eia.gov/totalenergy/data/monthly/archive/00351904.pdf [https://perma.cc/ZZ9V-M65B]. More recent data suggests sustained growth in renewables deployment. *See* U.S. ENERGY INFO. ADMIN., OCTOBER 2020 MONTHLY ENERGY REVIEW 130, https://www.eia.gov/totalenergy/data/monthly/archive/00352010.pdf [https://perma.cc/6ZYA-NVKM].

[44] U.S. ENERGY INFO. ADMIN., *supra* note 41, at 72.

[45] For background on the 7,286 megawatts of new solar capacity installed in 2015, see Press Release, Solar Energy Indus. Ass'n, U.S. Solar Market Sets New Record, Installing 7.3 GW of Solar PV in 2015 (Feb. 19, 2016), https://www.seia.org/news/us-solar-market-sets-new-record-installing-73-gw-solar-pv-2015 [https://perma.cc/WAJ9-NVRK]. For background on the 8,599 megawatts of new wind capacity installed in 2015, see *Wind Energy in the United States*, AWEA: AM. WIND ENERGY ASS'N, https://www.awea.org/wind-101/basics-of-wind-energy/wind-facts-at-a-glance [https://perma.cc/SV66-LWZT] (click the "2015" bar on the "Cumulative U.S. Wind Capacity" bar chart to view the underlying data referenced).

[46] The considerable challenge of balancing increasing amounts of variable renewable power generators with other resources has been vividly illustrated in a graphic known as the "duck chart" for its unusual shape. *See* CAL. INDEP. SYS. OPERATOR, WHAT THE DUCK CURVE TELLS US ABOUT MANAGING A GREEN GRID 3 fig.2 (2016), http://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf [https://perma.cc/93BX-KVPP].

forecasters' lives more difficult. The huge gap between the EIA's conservative projections and the actual data, for instance, is partly the product of profound changes to the policy landscape supporting renewable energy in the United States. As the 2000 AEO was going to print, federal tax credit support for wind power had just expired, and the EIA's projections assumed state-level policy support only for renewables going forward.[47] Little did the agency know that solar, wind, and other renewables would enjoy generous federal tax breaks, including tax credits and accelerated depreciation, for most of the forecast period.[48]

All sectors of the economy respond to the presence (or withdrawal) of public policy support. With its unusually dense regulatory framework, however, the U.S. energy economy appears particularly sensitive to changes in its policy landscape. Consider the well-documented impact that federal regulation at the wellhead has had on the supply of natural gas, causing severe shortages and annual losses of billions of dollars in social welfare.[49] At the other end of the spectrum, many commentators have identified the deregulation of energy markets as a major contributor to the 2000 to 2001 California energy crisis, also responsible for billions of dollars in social welfare losses.[50] The infamous boom-and-bust cycles resulting from periodic lapses and renewals of the production tax credit for wind between 2000 and 2016 offer more recent evidence of the energy industry's sensitivity to policy change.[51]

At this point, it should be clear why policy-makers face a particularly steep challenge when trying to anticipate, let alone predict, future developments in the energy domain. On the one hand, the sector's heightened sensitivity to changes in policy and regulation creates a serious endogeneity problem. On the other hand, the energy industry is far from immune to change triggered by exogenous factors, as evidenced by the series of technology and busi-

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[47] *See* U.S. ENERGY INFO. ADMIN., *supra* note 41, at 71.

[48] For a discussion of the federal tax incentives for renewables in general, and a critique of the inefficiencies of tax credits in particular, see Felix Mormann, *Beyond Tax Credits: Smarter Tax Policy for a Cleaner, More Democratic Energy Future*, 31 YALE J. ON REGUL. 303, 311–23 (2014).

[49] *See, e.g.*, Pierce, *supra* note 7, at 371–72 (discussing the gas shortages and associated welfare losses resulting from natural gas regulation). For a detailed account of the first twenty years of regulation of natural gas production, see STEPHEN G. BREYER & PAUL W. MACAVOY, ENERGY REGULATION BY THE FEDERAL POWER COMMISSION 56–88 (1974). For the (flawed) reasoning underlying the original mandate to regulate natural gas producers, see *Phillips Petroleum Co. v. Wisconsin*, 347 U.S. 672, 676–77, 685 (1954).

[50] For a thoughtful engagement with the factors contributing to the California energy crisis, see Timothy P. Duane, *Regulation's Rationale: Learning from the California Energy Crisis*, 19 YALE J. ON REGUL. 471, 507–17 (2002). *See generally* Mike Stenglein, *The Causes of California's Energy Crisis*, 16 NAT. RES. & ENV'T 237 (2002) (exploring the history of deregulation in California's energy market and the factors that led to its energy crisis).

[51] *See* Mormann, *supra* note 48, at 319.

ness innovations that have disrupted the U.S. energy economy in recent years—from hydraulic fracturing[52] to electric vehicles,[53] from solar photovoltaics and other renewables[54] to advanced metering infrastructure.[55]

To make matters worse, not only is the challenge itself formidable, the stakes, too, are higher than in many other industries. That is because power plants, pipelines, and many other energy assets have a useful life of forty years or more.[56] As policy-makers rely on (often flawed) projections about the future to craft policies and regulations for the next generation of energy assets, they commit the industry to a specific course. As new, better data becomes available, that course cannot be corrected, much less reversed without imposing considerable costs on utilities, ratepayers, and other stakeholders.[57]

Faced with the daunting, high-stakes task of anticipating the future armed with expert forecasts of, at best, dubious accuracy, energy policy-makers are increasingly embracing self-adjusting regulation as an insurance policy against forecast errors. Having established the general motivation for auto-adjusting regulation, it is time to explore its real-world implementation. The next Part of this Article surveys a representative sampling of self-adjusting energy regulation at the U.S. federal and state levels.

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[52] *See supra* note 38 and accompanying text.

[53] *See, e.g.*, Alexandra B. Klass, *Public Utilities and Transportation Electrification*, 104 IOWA L. REV. 545, 547 (2019) (noting that the transportation sector's ongoing electrification "will transform the automobile industry, the use of electricity on a broad scale and, as a result, our modern world").

[54] *See supra* notes 43–45 and accompanying text; *see also* Emily Kaldjian & Priya Barua, *The US Underwent a Quiet Clean Energy Revolution Last Year*, WORLD RES. INST. BLOG (Jan. 23, 2019), https://www.wri.org/blog/2019/01/us-underwent-quiet-clean-energy-revolution-last-year [https://perma.cc/57A3-RH68] (taking stock of soaring corporate demand for renewable energy and municipal clean energy pledges, among other changes).

[55] *See, e.g.*, Joel B. Eisen, *Smart Regulation and Federalism for the Smart Grid*, 37 HARV. ENV'T L. REV. 1, 10–21 (2013) (describing the challenges and opportunities associated with smart meters and other advanced metering infrastructure); Joel B. Eisen & Felix Mormann, *Free Trade in Electric Power*, 2018 UTAH L. REV. 49, 93–97 (assessing ongoing reforms to the utility business model in California and New York, made possible by advanced metering infrastructure).

[56] *See supra* note 5 and accompanying text.

[57] *See, e.g.*, Emily Hammond & Jim Rossi, *Stranded Costs and Grid Decarbonization*, 82 BROOK. L. REV. 645, 650–63 (2017) (discussing the challenges surrounding the stranded costs associated with utility investments made obsolete by a changing regulatory landscape); *see also* Alexandra B. Klass, *Future-Proofing Energy Transport Law*, 94 WASH. U. L. REV. 827, 830 (2017) (noting the tension among sunk costs, path dependency, and clean energy development at a time of growing concern over climate change and newly accessible abundant domestic fossil fuel reserves); Amy L. Stein, *Breaking Energy Path Dependencies*, 82 BROOK. L. REV. 559, 559–64 (2017) (offering a survey of the rich literature on path dependency and its application to the U.S. energy sector).

II. AUTOMATED REGULATION IN PRACTICE: AN ENERGY CASE STUDY

Dynamic regulation, in general, and automated, self-adjusting regulation, in particular, can take many forms. One might even go so far as to posit that all regulation entails some degree of dynamism, subject to the effort and process required to make adjustments. With their stringent substantive and procedural reform requirements, we might place constitutional provisions near the starting point of such a dynamism continuum. Self-adjusting automated regulation, with or without the use of artificial intelligence and smart algorithms, would be located closer to the end point of this continuum. Nestled between these two extremes, we would find the multiverse of approaches to adaptive regulation that pre-commit policy-makers to revisit, and possibly modify, their regulatory work product on a periodic basis to facilitate iterative learning and adjustment.[58]

Framing the dynamism of regulations solely in terms of their amenability to formal adjustments, however, would ignore the reality that policy-makers frequently use language that allows for evolving interpretation, and hence, application of a given provision without the need for formal revisions. To illustrate this informal dimension of dynamism, consider the pervasive use of technology standards for purposes of pollution control in environmental law.[59] As technology evolves, so does the regulator's interpretation of what constitutes

[58] For a snapshot of the literature on adaptive approaches to regulation based on repeat human intervention, across a range of substantive contexts, see generally Rosie Cooney & Andrew T.F. Lang, *Taking Uncertainty Seriously: Adaptive Governance and International Trade*, 18 EUR. J. INT'L L. 523 (2007) (discussing the benefits of adaptive governance in the face of uncertainty by analyzing the effectiveness of the World Trade Organization's (WTO) measures to combat the spread of invasive species); Robin Kundis Craig & J.B. Ruhl, *Designing Administrative Law for Adaptive Management*, 67 VAND. L. REV. 1 (2014) (asserting that adaptive management, though not appropriate for all agency decision-making, offers significant promise for specific areas of administrative law); Holly Doremus, *Adaptive Management as an Information Problem*, 89 N.C. L. REV. 1455 (2011) (rejecting the presumption of adaptive management's benefits and calling for a more rigorous analysis to inform decisions on whether to use adaptive management); Zachary J. Gubler, *Experimental Rules*, 55 B.C. L. REV. 129 (2014) (advocating for policy-makers' use of "experimental rules" to better address uncertainty and arguing for greater deference from courts towards such rules to promote their use); J.B. Ruhl, *Regulation by Adaptive Management—Is It Possible?*, 7 MINN. J.L. SCI. & TECH. 21 (2005) (examining the shortcomings of the implementation of adaptive management frameworks like the Endangered Species Act's Habitat Conservation Plan program and proposing measures for better deployment of adaptive management principles).

[59] *See, e.g.*, 33 U.S.C. § 1326(b) (mandating the use of "the best technology available" in the context of thermal discharges under the Clean Water Act); 42 U.S.C. § 300g-1(b)(4)(D) (requiring use of "the best technology, treatment techniques and other means which the Administrator finds . . . available" under the Safe Drinking Water Act); *id.* § 7411(g)(4) (setting forth the Clean Air Act's technology-based standards of performance for new stationary sources).

"the best available control technology," even though the underlying statutory provision has remained unchanged for decades.[60]

To complicate matters further, the literature has yet to converge on a common terminology for regulatory adaptation. Justin Pidot was among the first to propose a comprehensive typology that distinguishes between "static law" and "dynamic law," the latter comprised of durational, adaptive, and contingent regulations.[61] In their working paper, Lori Bennear and Jonathan Wiener differentiate between automated and discretionary types of adaptive regulation.[62] This Article's working definition of automated regulation encompasses durational as well as contingent approaches per Pidot and maps neatly with Bennear and Wiener's definition of automated adaptive regulation. Within automated regulation, I distinguish two general classes, based on the independent variable or metric that triggers a regulation to adapt. In the first class of automated regulations, change occurs as a relatively straightforward function of time.[63] The second class uses more dynamic market-based factors as the trigger for regulatory adjustment.[64]

A. Time-Sensitive Regulatory Automation

Perhaps the most basic example of time-triggered automated regulation is that of a sunset clause incorporated to terminate a statute, provision, program, or agency at a specified date.[65] The addition of an expiration date can serve a variety of purposes. In some cases, it indicates the regulator's awareness that the provision in question is of an experimental nature and that its impact and utility should be revisited at the end of a trial period.[66] In other cases, the regulator gives finite life to regulations because of budgetary motives, such as to

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[60] *See, e.g.*, Alaska Dep't of Env't Conservation v. EPA, 540 U.S. 461, 468–70, 472 (2004) (quoting 42 U.S.C. § 7475(a)(4)) (illustrating the dynamic interpretation of technology standards for air pollution control and their sensitivity to technological progress).

[61] *See* Pidot, *supra* note 3, at 140–41.

[62] *See generally* Lori S. Bennear & Jonathan B. Wiener, *Adaptive Regulation: Instrument Choice for Policy Learning Over Time* (Working Paper, 2019), https://www.hks.harvard.edu/sites/default/files/centers/mrcbg/files/Regulation%20-%20adaptive%20reg%20-%20Bennear%20Wiener%20on%20Adaptive%20Reg%20Instrum%20Choice%202019%2002%2012%20clean.pdf [https://perma.cc/TWM4-T5CN].

[63] *See* discussion *infra* Part II.A.

[64] *See* discussion *infra* Part II.B.

[65] For an introduction to the historic roots and continued prevalence of sunset clauses, see, for example, Jacob E. Gersen, *Temporary Legislation*, 74 U. CHI. L. REV. 247, 249–61 (2007). In the United States, sunset clauses have been particularly popular as limitations on the continued existence of government agencies. *See, e.g.*, Dan R. Price, *Sunset Legislation in the United States*, 30 BAYLOR L. REV. 401, 401 (1978); Anthony R. Licata, Note, *Zero-Base Sunset Review*, 14 HARV. J. ON LEGIS. 505, 506–16 (1977).

[66] For a thoughtful discussion of the challenges and opportunities of experimental legislation and regulation, see Sofia Ranchordás, *Sunset Clauses and Experimental Regulations: Blessing or Curse for Legal Certainty?*, 36 STATUTE L. REV. 28, 38–44 (2015).

limit the burden on American taxpayers imposed by tax breaks.[67] Finally, sunset provisions can reflect the regulator's anticipation of a future change in circumstances that calls into question the continued utility of an initially warranted piece of legislation or regulation.[68] It is this last use of sunset clauses that policy-makers resort to in their quest for insurance against flaws in the forecasts and assumptions that inform their regulatory choices.

The Section 1603 cash grant for renewable energy assets, first created under the American Recovery and Reinvestment Act of 2009 (ARRA),[69] illustrates this dynamic. When the financial crisis of 2008 to 2009 led most banks, insurance companies, and other tax equity investors to pull out of renewable energy,[70] Congress included a special cash subsidy in its ARRA stimulus package to keep the then-fledgling solar and wind industries afloat.[71] At the time, federal legislators were unsure how severe and long-lasting the economic downturn caused by the financial crisis would be. Thus, they endowed the Section 1603 grant, adopted as part of a *temporary* relief package,[72] with a one-year sunset clause.[73] When, one year later, the economy in general and the re-

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[67] For an intriguing account of the complex relationship between sunset clauses and budget constraints, including the so-called Byrd Rule, see Alli Sutherland, Note, *Ghosting in Tax Law: Sunset Provisions and Their Unfaithfulness*, 46 HASTINGS CONST. L.Q. 479, 493–95 (2019); see also Rebecca M. Kysar, *The Sun Also Rises: The Political Economy of Sunset Provisions in the Tax Code*, 40 GA. L. REV. 335, 402–06 (2006) (analyzing sunset provisions within the context of tax policy and concluding that the provisions exacerbate special interest-driven inefficiencies in government).

[68] *See* Rebecca M. Kysar, *Dynamic Legislation*, 167 U. PA. L. REV. 809, 824 (2018) (referring to sunset clauses as a type of "prompting" instrument designed to induce later legislative or regulatory action).

[69] American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, § 1603, 123 Stat. 115, 364–66 (codified as amended at 26 U.S.C. § 48).

[70] Between 2007 and 2009, the market for tax equity, required to benefit from federal tax incentives for solar, wind, and other renewables, contracted by over 8%, from $6.1 billion in 2007 to $1.2 billion in 2009. *See* BIPARTISAN POL'Y CTR., REASSESSING RENEWABLE ENERGY SUBSIDIES: ISSUE BRIEF 10 (2011), https://bipartisanpolicy.org/wp-content/uploads/2019/03/BPC_RE-Issue-Brief_3-22.pdf [https://perma.cc/ZJW9-9LKM].

[71] Specifically, the Section 1603 cash grant gave eligible renewable energy developers the option to receive a cash grant from the Department of Treasury for up to 30% of their qualifying costs in lieu of their traditional production or investment tax credits. *See* U.S. DEP'T OF TREASURY, PAYMENTS FOR SPECIFIED ENERGY PROPERTY IN LIEU OF TAX CREDITS UNDER THE AMERICAN RECOVERY AND REINVESTMENT ACT OF 2009, at 5 (2011), https://www.treasury.gov/initiatives/recovery/Documents/B%20Guidance%203-29-11%20revised%20(2)%20clean.pdf [https://perma.cc/TY4U-TBNU].

[72] The official title of American Recovery and Reinvestment Act's closely related Section 1705, "Temporary Program for Rapid Deployment of Renewable Energy and Electric Power Transmission Projects," reflects the program's temporary nature. *See* § 1705, 123 Stat. at 145 (codified as amended at 42 U.S.C. § 16516) (expired 2011)).

[73] *See* § 1603, 123 Stat. at 302 (codified as amended at I.R.C. § 48). For a critical assessment of Section 1603 grant's impact on job creation, see Memorandum from the Subcomm. on Oversight & Investigations Majority Staff, Comm. on Energy & Com. on Where Are the Jobs?—The Elusiveness of Job Creation Under the Section 1603 Grant Program for Renewable Energy to Members, Energy, and Commerce Committee 3 (June 18, 2012), https://republicans-energycommerce.house.gov/sites/

newables industry in particular continued to struggle, Congress extended the Section 1603 cash grant by another year as part of the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010.[74]

Other manifestations of time-sensitive automated regulation offer greater nuance than the binary "on/off" switch of sunset clauses. The Consolidated Appropriations Act of 2016 (CAA),[75] for example, not only gave solar and wind an extra five years of federal tax credit support; it also provided for a gradual phase-down of the value of these tax incentives. Congress scheduled the production tax credit for wind[76] to phase down in twenty percent increments annually starting in 2017 before phasing out altogether at the end of 2019.[77] The investment tax credit for solar is similarly slated to phase down, albeit in slightly smaller annual increments, starting in 2020 and bottoming out at ten percent of qualifying expenditures for commercial installations, while going away entirely for residential installations, both at the end of 2021.[78]

A schedule of gradual reductions in the value of public policy support, such as that included in the CAA, reflects policy-makers' attempts to anticipate technology learning, cost improvements, and other market developments in the pertinent industries. To the same end, policy-makers outside the United States have long included standard annual degression rates in their support programs for emerging energy technologies.[79] Such time-sensitive triggers for automated regulation, however, rarely amount to more than a crude approximation of future industry development. After all, even the most nuanced time-sensitive regulation assumes that change occurs at a linear, predictable pace that can be

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republicans.energycommerce.house.gov/files/analysis/20120618greenjobs.pdf [https://perma.cc/9ECZ-GBZZ].

[74] Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010, Pub. L. No. 111-312, § 707, 124 Stat. 3296, 3312 (codified as amended at I.R.C. § 48).

[75] Consolidated Appropriations Act, 2016, Pub. L. No. 114-113, §§ 301–304, 129 Stat. 2242, 3038–40 (2015) (codified as amended at I.R.C. §§ 25D, 45, 48).

[76] *See* § 301, 129 Stat. at 3038 (codified as amended at I.R.C. § 45).

[77] *See* Felix Mormann, *Fading into the Sunset: Solar and Wind Energy Get Five More Years of Tax Credits with a Phase-down*, 47 TRENDS 9, 9–11 (2016), https://www.americanbar.org/groups/environment_energy_resources/publications/trends/2015-2016/may-june-2016/fading_into_the_sunset/ [https://perma.cc/B3LU-HKX2] (discussing the most recent extension of tax credits for wind and solar, along with their eventual phasing down and out).

[78] *See* I.R.C. § 25D (stating homeowner's personal tax credit for residential properties); *id.* § 48 (stating the investment tax credit for commercial solar properties).

[79] *See, e.g.*, Lincoln L. Davies & Kirsten Allen, *Feed-in Tariffs in Turmoil*, 116 W. VA. L. REV. 937, 949, 954–57 (2014) (describing Germany's inclusion of standard degression rates in its feed-in tariffs to promote solar, wind, and other renewables, beginning in the year 2000); *see also* MIGUEL MENDONÇA ET AL., POWERING THE GREEN ECONOMY: THE FEED-IN TARIFF HANDBOOK 49 (2009) (suggesting that policy-makers set degression rates based on the slope of a technology's learning curve with higher degression rates for solar photovoltaics and other technologies with more rapidly declining costs).

captured through gradual adaptation over time. In reality, industries, technologies, and markets change in response to a much more complex mix of factors. In the context of emerging energy technologies, for example, technology learning and cost improvements are primarily a function of deployment and attendant economies of scale, not the mere passage of time.[80] Accordingly, policy-makers seeking to brace for future industry trends without the gamble of committing to a specific timeline—a timeline often (mis)informed by expert forecasts of dubious accuracy—are better off turning to market-based factors as the trigger for regulatory adaptation.

B. Market-Sensitive Regulatory Automation

Once policy-makers decide to replace the passage of time with a market-based trigger for regulatory adaptation, they must determine which market indicator, or mix of indicators, best captures the changing circumstances to which their regulatory regime shall adjust. A policy-maker concerned with the impact of macro-economic developments on its programs, for instance, may choose to incorporate automatic adjustments based on overall inflation. The federal production tax credit for wind power has been subject to such inflation indexing since its inception.[81] First created under the Energy Policy Act of 1992[82] with a value of fifteen dollars per megawatt-hour of wind-powered electricity, a series of adjustments to account for general price inflation across the U.S. economy have gradually increased the tax credit's value to twenty-five dollars per megawatt-hour as of 2020.[83]

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[80] *See, e.g.*, PATRICK HEARPS & DYLAN MCCONNELL, MELBOURNE ENERGY INST., RENEWABLE ENERGY TECHNOLOGY COST REVIEW 7 (2011), https://cleanenergysolutions.org/pt-br/resources/renewable-energy-technology-cost-review [https://perma.cc/XA4M-F7EZ] (noting the extreme importance of deployment in reducing cost). German policy-makers learned a painful (and costly) lesson when the country's solar incentives' standard degression rates failed to keep up with tumbling prices for solar panels, inverters, and other hardware, following consolidation of the Chinese solar manufacturing industry in the early 2010s. *See* Felix Mormann et al., *A Tale of Three Markets: Comparing the Renewable Energy Experiences of California, Texas, and Germany*, 35 STAN. ENV'T L.J. 55, 97 (2016). Even the thoughtful suggestion to replace annual degression rates with monthly degression rates, although more granular, attaches regulatory adaptation to the wrong independent variable. *See* CLAIRE KREYCIK ET AL., NAT'L RENEWABLE ENERGY LAB'Y, INNOVATIVE FEED-IN TARIFF DESIGNS THAT LIMIT POLICY COSTS 13–14 (2011), http://www.nrel.gov/docs/fy11osti/50225.pdf [https://perma.cc/LQ4U-23JV].

[81] *See* I.R.C. § 45I(b)(2).

[82] Energy Policy Act of 1992, Pub. L. No. 102-486, 106 Stat. 2776 (codified as amended in scattered sections of 16 and 42 U.S.C.).

[83] For the production tax credit's most recent inflation adjustment, see Credit for Renewable Electricity Production, Refined Coal Production, and Indian Coal Production, and Publication of Inflation Adjustment Factors and Reference Prices for Calendar Year 2020, 85 Fed. Reg. 28,698, 28,699 (May 13, 2020). The $25 mark is the reference point for the phase-out calculations laid out in the Consolidated Appropriations Act of 2016. *See also supra* note 75 and accompanying text.

Of course, inflation indexing aggregates price changes across a multitude of inputs at an economy-wide scale and, hence, paints with a broad brush. But nothing prevents policy-makers from focusing on a specific input's price development, thereby using a scalpel rather than the proverbial axe to deliver more tailored, automatic adjustments to their regulations. The paradigmatic example of such a tailored approach to automated regulation is the fuel adjustment clause. For more than a century, utility regulators across the United States have tethered rates for electricity and natural gas, among others, to the price of specific fuel inputs.[84] First considered by a few pioneering state regulators in response to volatile prices for coal during World War I, automatic fuel adjustment clauses quickly found a devout following, spreading to more than forty states by 1960.[85]

To fully appreciate the value proposition of fuel adjustment clauses, one must first understand the framework of rate regulation that has governed the U.S. utility industry for most of the twentieth century and remains in force for about half of the country today.[86] Historically, energy utility companies have been subject to monopoly regulation, granting them an exclusive service territory in exchange for a universal duty to serve clients in that territory at rates subject to the responsible state commission's regulatory approval.[87] These rate case proceedings require state regulators to probe into the utility's capital and operating costs, historic and projected sales volume, and many other data

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[84] *See* Foy, *supra* note 7, at 664–65; Trigg, *supra* note 7, at 964.

[85] *See* Foy, *supra* note 7, at 669, 671 (reporting that, in Texas alone, more than 400 municipalities permitted automatic fuel adjustment clauses by 1960); *see also* R. Mark Isaac, *Fuel Cost Adjustment Mechanisms and the Regulated Utility Facing Uncertain Fuel Prices*, 13 BELL J. ECON. 158, 159 (1982) (noting that, by 1976, forty-three states featured fuel adjustment clauses in their utility regulation). For a snapshot of the proliferation of fuel adjustment clauses for natural gas, see *City of Chicago v. Illinois Commerce Commission*, 150 N.E.2d 776, 779 (Ill. 1958) (noting that, by the mid-1950s, sixty-five gas distributing companies in twenty-six states had adjustment clauses in their rate schedules based on the cost of purchased gas).

[86] For an overview of the varied state of regulation and restructuring in energy markets across the United States, see generally STEVE ISSER, ELECTRICITY RESTRUCTURING IN THE UNITED STATES: MARKETS AND POLICY FROM THE 1978 ENERGY ACT TO THE PRESENT (2015) (providing a comprehensive examination of the U.S. electricity industry's transformation through economic, legal, regulatory, and political lenses). For a helpful visualization, see *Deregulated Energy States & Markets*, ELEC. CHOICE, https://www.electricchoice.com/map-deregulated-energy-markets/ [https://perma.cc/DEK4-JEYP] (2020). Notably, even in states that allow ratepayers a choice among various retail electricity providers, delivery of electricity to the consumer is still monopoly-regulated using the time-honored process of rate cases.

[87] For insightful accounts of the history of utility rate regulation, see Joel B. Eisen, *FERC's Expansive Authority to Transform the Electric Grid*, 49 U.C. DAVIS L. REV. 1783, 1797–1812 (2016); Emily Hammond & David B. Spence, *The Regulatory Contract in the Marketplace*, 69 VAND. L. REV. 141, 149–54 (2016); see also William Boyd, *Just Price, Public Utility, and the Long History of Economic Regulation in America*, 35 YALE J. ON REGUL. 721, 722 (2018) (tracing modern utility rate regulation all the way back to the Aristotelian concept of corrective justice).

points to arrive at a "just and reasonable" rate that balances the legitimate interests of consumers with those of the utility and its investors.[88]

Due to their data intensity and the need to reconcile a multitude of competing interests, rate cases have become notorious as a "time-consuming regulatory process, plagued by bureaucratic and administrative delay."[89] When fuel costs go up, the resulting regulatory lag poses a serious threat to the cash flow and, ultimately, financial viability of utilities, especially during times of rapid inflation.[90] The hike in oil prices during the 1970s energy crisis illustrates this dynamic with utilities' fuel expenditures nearly doubling from one year to the next.[91] Going through the normal process of applying to the state public utility commission for approval of a rate increase, followed by a complex and potentially controversial rate case proceeding, a utility would have to wait months, if not years, before being allowed to recover its increased fuel costs from consumers. Automated regulation through self-executing fuel adjustment clauses offers a timely alternative to mitigate the negative consequences of regulatory inertia.[92]

The precise mechanics of fuel adjustment clauses vary across states and utilities.[93] They all share a common denominator, however—a formulaic element that automatically adjusts the utility's revenue requirement as a function

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[88] *See, e.g.*, FPC v. Hope Nat. Gas, 320 U.S. 591, 603 (1944) ("The rate-making process . . . i.e., the fixing of 'just and reasonable' rates, involves a balancing of the investor and the consumer interests."); *see also* James Ming Chen, *Speculative Undertakings: Rate Regulation as a Branch of Corporate Finance*, 35 YALE J. ON REGUL. 779, 788–95 (2018) (describing utility ratemaking as a variation on the financial theme of uncertainty).

[89] Marshall A. Leaffer, *Automatic Fuel Adjustment Clauses: Time for a Hearing*, 30 CASE W. RSRV. L. REV. 228, 229 (1980); *see also* Foy, *supra* note 7, at 663 (discussing the onerous complexity of utility rate case proceedings); Shelley Welton & Joel Eisen, *Clean Energy Justice: Charting an Emerging Agenda*, 43 HARV. ENV'T L. REV. 307, 322 (2019) (criticizing the "byzantine process" before state public utility commissions and other governing bodies of the U.S. energy economy). For a comprehensive overview of utility regulation and the kaleidoscope of actors and competing interests, see generally CARL PECHMAN, REGULATING POWER: THE ECONOMICS OF ELECTRICITY IN THE INFORMATION AGE (1993).

[90] *See* David P. Baron & Raymond R. De Bondt, *On the Design of Regulatory Price Adjustment Mechanisms*, 24 J. ECON. THEORY 70, 70 (1981); Pierce, *supra* note 7, at 373 ("[F]uel costs constitute such a large proportion of a utility's total costs that any substantial regulatory lag in approving rate increases to reflect fuel cost increases can cause the rapid financial ruin of an otherwise healthy utility.").

[91] *See* Leaffer, *supra* note 89, at 228 (reporting utility fuel costs of $6.7 billion for 1973, then rising to $11.8 billion in 1974); *see also* Baron & De Bondt, *supra* note 90, at 71 (discussing the staggering volume of rate increases required between 1973 and 1976).

[92] *See, e.g.*, Leaffer, *supra* note 89, at 230 ("The automatic fuel adjustment clause . . . appears to solve the cash flow dilemma resulting from regulatory lag and eliminates the public expense of lengthy administrative hearings.").

[93] *See, e.g.*, Foy, *supra* note 7, at 673 (offering a snapshot of the variegated use of fuel adjustment clauses across jurisdictions); Trigg, *supra* note 7, at 974.

of its fuel expenditures and translates that adjustment into a higher (or lower)[94] rate.[95] The utility is then authorized to charge the new, adjusted rate to its customers without the need for regulatory approval from the state public utility commission.[96] A similar automatic mechanism is used, albeit less frequently, to adjust utility rates to changes in applicable taxes.[97]

The gradual shift away from coal-fired electricity generation, the advent of hydraulic fracturing, and the increasing globalization of natural gas markets have reduced the price volatility of fossil fuel inputs for U.S. utilities in recent years.[98] The proliferation of solar, wind, and other renewables with zero fuel costs on the grid may, one day, altogether eliminate the need for automatic fuel adjustment clauses. In the meantime, however, the rapid improvements and attendant cost reductions in clean energy technologies present their own challenges for policy-makers. If rapid *inflation* in fossil fuel prices made the case for fuel adjustment clauses,[99] then rapid *deflation* in technology cost is making a persuasive argument for similarly automated regulation of clean energy incentives.

In electric transportation, for example, the cost of batteries—historically accounting for the lion's share of a vehicle's production cost—has plummeted in recent years. In 2015, the traction battery made up over 57% of the total cost of a midsize car in the United States. As of early 2019, that number has dropped to merely 33%, a staggering reduction over only four years.[100] Federal policy-makers have sought to anticipate these cost savings with a tiered phase-out of their tax incentives for electric vehicles.[101] Following the conventional wisdom that technology learning and cost improvements are a function of de-

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[94] It is worth pointing out that, in theory, fuel adjustment clauses are agnostic as to the direction (upward or downward) in which a utility's rate is adjusted. Their characterization as "escalator clause[s]" in parts of the literature is, strictly speaking, a mischaracterization, albeit one that captures the more common application of these clauses. *See* Leaffer, *supra* note 89, at 231.

[95] *See* Baron & De Bondt, *supra* note 90, at 71.

[96] *See, e.g.*, Foy, *supra* note 7, at 663 ("[A] provision which, without formal proceedings, increases or decreases utility rates in proportion to increases or decreases in an operating expense."); Leaffer, *supra* note 89, at 230.

[97] *See* William K. Jones, *An Example of a Regulatory Alternative to Antitrust: New York Utilities in the Early Seventies*, 73 COLUM. L. REV. 462, 492 (1973); Trigg, *supra* note 7, at 965 n.6.

[98] *See, e.g.*, *Henry Hub Natural Gas Spot Price*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm [https://perma.cc/S3AP-XN8P] (Dec. 16, 2020).

[99] *See* Paul L. Joskow, *Inflation and Environmental Concern: Structural Change in the Process of Public Utility Price Regulation*, 17 J.L. & ECON. 291, 314 (1974) ("Rapid inflation had quickly changed a very passive and inactive 'rate of return' regulatory process into a very active and continual process of administrative rate of return review." (emphasis omitted)).

[100] *See* Nathaniel Bullard, Opinion, *Electric Vehicle Battery Shrinks and So Does the Total Cost*, BLOOMBERG (Apr. 12, 2019), https://www.bloomberg.com/opinion/articles/2019-04-12/electric-vehicle-battery-shrinks-and-so-does-the-total-cost [https://perma.cc/8PKC-7EPT].

[101] *See* I.R.C. § 30D (West 2019) (codified at Further Consolidated Appropriations Act, 2020, Pub. L. No. 116-94, § 127(b), (c)(2)(B), 133 Stat. 2534, 3231–32 (2019)).

ployment, more so than time,[102] the federal tax credit phases down to fifty percent once a manufacturer has sold 200,000 vehicles into the U.S. market, dropping to 25% half a year later before disappearing altogether another six months later.[103]

Solar power technology has posed perhaps the greatest challenge for policy-makers seeking to keep their programs up to date with the latest industry trends and development. That is because the dramatic cost reductions observed in recent years have been the product not only of increased deployment and attendant economies of scale, but also of other harder-to-predict drivers, such as the consolidation process that followed a period of overproduction and cut-throat price competition among Chinese manufacturers of solar panels and other equipment.[104] Add to that geopolitically motivated price increases stemming from tariffs imposed as part of the "solar trade wars,"[105] and it is easy to appreciate the immense challenge for policy-makers trying to stay abreast of the latest trends in this fast-changing industry.

The stakes are high. Failure to keep up can have disastrous consequences, as illustrated by strong popular pushback against support schemes in Spain or Germany—two former leaders in solar deployment that failed to keep up with tumbling prices for solar photovoltaic equipment.[106] The German public's strong stance against fossil fuels and nuclear power, coupled with hastily implemented reductions in solar subsidies, allowed the country to continue on its pro-renewables course.[107] Spanish regulators, on the other hand, succumbed to fierce popular backlash by first suspending, and, ultimately, dismantling their

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[102] *See supra* note 80 and accompanying text.

[103] *See* I.R.C. § 30D(e)(2)–(3).

[104] For an insightful account of the "ballooning of China-based solar manufacturers—Chinese solar-manufacturing capacity," the resulting glut of solar modules and depressed prices, and the ensuing consolidation, see JEFFREY BALL ET AL., STAN. STEYER-TAYLOR CTR. FOR ENERGY POL'Y & FIN., THE NEW SOLAR SYSTEM: CHINA'S EVOLVING SOLAR INDUSTRY AND ITS IMPLICATIONS FOR COMPETITIVE SOLAR POWER IN THE UNITED STATES AND THE WORLD 45 (2017), https://law.stanford.edu/wp-content/uploads/2017/03/2017-03-20-Stanford-China-Report.pdf [https://perma.cc/3N5U-32Y9].

[105] For an account of the back-and-forth in tariffs and other trade sanctions imposed on solar panels and other hardware, including related litigation before the WTO, see Mormann et al., *supra* note 80, at 84 & n.145.

[106] *See, e.g.*, Nora Bonatz et al., *A Comparative Study of the Interlinkages Between Energy Poverty and Low Carbon Development in China and Germany by Developing an Energy Poverty Index*, 183 ENERGY & BLDGS. 817, 824–25, 828 (2019) (discussing energy affordability challenges resulting from Germany's overly generous support for solar and other renewables); Euan Phimister et al., *The Dynamics of Energy Poverty: Evidence from Spain*, 4 ECON. ENERGY & ENV'T POL'Y 153, 157 (2015) (noting the growing energy poverty in Spain that accompanied the country's solar boom).

[107] *See, e.g.*, Davies & Allen, *supra* note 79, at 957 (describing "Germany's effort to transform its energy system away from nuclear and conventional sources").

solar support program—in some cases even retroactively.[108] At the other end of the spectrum, taking a conservative approach to public policy support for solar and other emerging energy technologies can avoid the budgetary concerns associated with overpaying. But such frugality may come at the expense of policy efficacy, as incentive levels prove too low to deliver the desired deployment.[109] Simply speaking, policy-makers are under enormous pressure to get, and keep, the price right when it comes to support programs for emerging energy technologies.[110] Many jurisdictions assign this task to the same regulators that oversee local utilities and their rate case proceedings. It should not come as a huge surprise, therefore, that some of these regulators, inspired by decades of success with automatic fuel adjustment clauses, have turned to regulatory automation for help.

When Oregon launched its Solar Photovoltaic Volumetric Incentive Program in 2010, incentive rates of up to $0.65 per kilowatt-hour of solar-generated electricity[111] were soon criticized as too high relative to technology and installation costs, providing windfall profits to developers.[112] Available capacity was, indeed, oversubscribed during early enrollment rounds, leading the Oregon Public Utility Commission (OPUC) to convert capacity allocation

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[108] For a detailed account of the unraveling of Spain's solar support program, see Toby Couture, *Pain in Spain: New Retroactive Changes Hinder Renewable Energy*, RENEWABLE ENERGY WORLD (Apr. 19, 2013), https://www.renewableenergyworld.com/articles/2013/04/pain-in-spain-new-retroactive-changes-hinders-renewable-energy.html [https://perma.cc/A3F4-NRJC].

[109] The City of Palo Alto's 2012 solar support scheme illustrates this dilemma, with incentives too low to promote any solar deployment during the first three years of its existence. *See* Gary M. Lucas, Jr. & Felix Mormann, *Betting on Climate Policy: Using Prediction Markets to Address Global Warming*, 52 U.C. DAVIS L. REV. 1429, 1474 (2019). Argentina experienced similar problems when its 2006 wind support program delivered only minimal deployment. *See* MENDONÇA ET AL., *supra* note 79, at 57.

[110] One way out of this dilemma is, of course, for policy-makers to choose market-based mechanisms, instead of their price-based counterparts, to promote emerging energy technologies. For a primer on the distinction between both and their global proliferation, see INT'L ENERGY AGENCY, DEPLOYING RENEWABLES 2011: BEST AND FUTURE POLICY PRACTICE 161–71 (2011), https://www.iea.org/reports/deploying-renewables-2011-best-and-future-policy-practice [https://perma.cc/J32M-AUZM]; INT'L ENERGY AGENCY, DEPLOYING RENEWABLES: PRINCIPLES FOR EFFECTIVE POLICIES 92–95 (2008), https://www.iea.org/reports/deploying-renewables-principles-for-effective-policies [https://perma.cc/UM8E-K82Z]; see also Felix Mormann, *Re-allocating Risk: The Case for Closer Integration of Price- and Quantity-Based Support Policies for Clean Energy*, 27 ELEC. J. 9, 10 (2014) (making the case for joint implementation of price-based and market-based policies).

[111] *See* OR. PUB. UTIL. COMM'N, SOLAR PHOTOVOLTAIC VOLUMETRIC INCENTIVE PROGRAM: REPORT TO THE LEGISLATIVE ASSEMBLY 3 (2013), https://www.oregonlegislature.gov/citizen_engagement/Reports/2013_PUC_Solar%20Photovoltaic%20Volumetric%20Incentive%20Program.pdf [https://perma.cc/83PJ-7Y35].

[112] *See, e.g.*, *In re* Pub. Util. Comm'n of Or.: Solar Voltaic Comments and Recommendations, No. UM 1505, at 3 (Feb. 11, 2011) (statement of Dave Sullivan) ("The incentive rates were at least 30 percent too high to balance the available capacity with demand.").

from a first-come, first-served system to a lottery.[113] Still, the OPUC had done its homework and appreciated the considerable challenge of getting—and keeping—their solar incentives at appropriate levels amidst a fast-changing industry. From the beginning, the Oregon program included an automatic rate adjustment mechanism, allowing incentive rates to rise or fall from one enrollment round to the next.[114]

Unlike the fuel adjustment clauses that inspired its adoption, Oregon's rate adjustment mechanism was not tethered to the price of solar panels, inverters, or any other *input*. Instead, the policy-maker decided to use an *output*-oriented indicator—observed solar deployment—as the trigger for regulatory adaptation. When demand exceeds available capacity by a specified margin, the mechanism reduces the rate for the following round and, conversely, raises it if an enrollment round is undersubscribed.[115] These automatic adjustments were originally limited to increments of ten percent, but eventually modified to allow for rate adjustments of up to twenty percent.[116] Other jurisdictions have adopted similar frameworks of regulatory automation as part of their clean energy policies.[117]

The output-oriented version of automated regulation offers two distinct advantages over fuel adjustment clauses and other input-focused mechanisms. First, it expressly acknowledges the multitude of factors, many of them subject to frequent and sometimes dramatic changes, that determine the overall per-unit generation cost of solar installations.[118] Solar panels, inverters, and other hardware, for example, have undergone a series of dramatic price drops over

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[113] *See id.* at 4–5.

[114] *See* OR. PUB. UTIL. COMM'N, *supra* note 111, at 6.

[115] *See id.* at 7–8.

[116] *Id.* at 7.

[117] *See, e.g.*, CAL. ENERGY COMM'N, INTEGRATED ENERGY POLICY REPORT: 2013 IEPR 92–93 (2013) (discussing California's Renewable Market Adjusting Tariff), https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report [https://perma.cc/G9AA-2U35]; Davies & Allen, *supra* note 79, at 955 (referencing the "breathing cap" in Germany's renewable energy support schemes). *But see* Winding Creek Solar LLC v. Peterman, 932 F.3d 861, 865 (9th Cir. 2019) (invalidating California's Re-MAT program on preemption grounds); Frank Jossi, *What Goes into Calculating Minnesota's Groundbreaking "Value of Solar" Rate?*, MIDWEST ENERGY NEWS (Sept. 9, 2019), https://energynews.us/2019/09/09/midwest/what-goes-into-calculating-minnesotas-groundbreaking-value-of-solar-rate/ [https://perma.cc/2TF4-RBQB] (exploring the eight key variables, such as avoided fuel cost or avoided distribution capacity cost, feeding into the complicated formula that automatically calculates the rate for electricity from community solar projects in Minnesota).

[118] The prevailing metric in the literature for such per-unit generation cost is the "levelized cost of electricity," representing the cost per kilowatt-hour of electricity generated based on a power plant's capital costs, fuel costs, fixed and variable costs for operation and maintenance, and financing costs over the operational life of the plant. *See, e.g.*, U.S. ENERGY INFO. ADMIN., LEVELIZED COST AND LEVELIZED AVOIDED COST OF NEW GENERATION RESOURCES IN THE ANNUAL ENERGY OUTLOOK 2015, at 1 (2015), https://www.eia.gov/outlooks/archive/aeo15/pdf/electricity_generation_2015.pdf [https://perma.cc/CG3C-XDX6].

the past decade alone.[119] Soft costs, such as those incurred for permitting, installation, and financing, are subject to similar fluctuations and account for an ever-increasing share of overall project cost.[120] It is a testament to the Oregon regulator's diligence that its solar incentive program also sought to incorporate site-specific factors such as variations in solar resource quality across different areas of the state.[121]

The second key advantage of Oregon's rate adjustment mechanism lies in the output-oriented approach's capacity to operate as a steering tool. Fuel adjustment clauses serve a primarily reactive purpose—adjusting utility rates to reflect past changes in fuel prices. Output-based adjustment mechanisms, such as Oregon's solar program, also react to changes in the overall cost of solar installations. In addition, however, use of specific deployment benchmarks as triggers for regulatory adaptation, in the form of an automatic rate adjustment upwards or downwards, enables the Oregon policy-maker to guide and, ultimately, control the overall pace and volume of deployment.[122] This steering function is all the more important in light of the lingering uncertainty over the impact that ramping up the share of solar, wind, and other weather-dependent renewables with variable output will have on the reliability of electric service.[123]

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[119] *See, e.g.*, RAN FU ET AL., NAT'L RENEWABLE ENERGY LAB'Y, U.S. SOLAR PHOTOVOLTAIC SYSTEM COST BENCHMARK: Q1 2017, at vi (2017), https://www.nrel.gov/docs/fy17osti/68925.pdf [https://perma.cc/2ZTM-U9RG] (reporting approximately 30% cost declines for utility-scale solar systems from 2016 to 2017).

[120] *Id.* at viii (reporting soft costs as responsible for 68% of overall costs in residential solar projects). For an introduction to soft costs and the factors that drive them, see Felix Mormann, *Enhancing the Investor Appeal of Renewable Energy*, 42 ENV'T L. 681, 710–25 (2012).

[121] As a tribute to regional variations in insolation, Oregon's solar incentive program divides the state into four different regions, each with its own rate. *See* OR. PUB. UTIL. COMM'N, INVESTIGATION INTO THE EFFECTIVENESS OF SOLAR PROGRAMS IN OREGON, at iv, 8 (2014), https://olis.leg.state.or.us/liz/2015R1/Downloads/CommitteeMeetingDocument/49006 [https://perma.cc/FA8Z-SD35].

[122] To be clear, increases in electricity rates following application of a fuel adjustment clause should, following basic economic theory, affect demand, but the general lack of price elasticity, especially among residential ratepayers, limits the size of this effect. More importantly, it comes as an afterthought whereas output-based rate adjustments, such as that of Oregon's solar scheme, require the policy-maker to set specific output goals as the starting point of any adaptation.

[123] Critics of the large-scale build-out of solar and wind power often claim that the intermittent output profiles of these renewable resources will jeopardize the stability of the electrical grid. According to one commentator, for example, "[w]hen renewables supply 20 to 30 percent of all electricity, many utility-energy engineers predict, the system will no longer be able to balance supply and demand." *See* Charles C. Mann, *What if We Never Run Out of Oil?*, THE ATLANTIC (May 2013), https://www.theatlantic.com/magazine/archive/2013/05/what-if-we-never-run-out-of-oil/309294/ [https://perma.cc/X6R6-LGMP]. To be sure, empirical evidence suggests that the grid can likely absorb larger quantities of intermittent renewables. Germany, for example, tripled the share of solar and wind power in its electricity mix between 2006 and 2013 to 26%, all the while managing to reduce average annual outage times. *See* Mormann et al., *supra* note 80, at 71, 86.

III. Toward a Normative Theory of Automated Regulation

So far, I have explained the conceptual appeal of automated regulation for policy-makers as insurance against forecast errors and presented a series of case studies of regulatory automation to illustrate its practical relevance. But what does the future hold for automated regulation? Are fuel adjustment clauses and their progeny just a brief stopover along the evolutionary path toward algorithmic governance? Or should regulatory automation in its current simplistic, yet tried-and-true, form become a more widely used, permanent feature in the policy-making toolkit?

To answer these questions, this Part surveys and weighs the most prominent arguments for and against automated regulation, probes into its ideal scope of application, and offers recommendations for the proper relationship between market-based auto-regulations and the underlying markets. What emerges from this exercise is the first step toward conceptualizing a normative theory of regulatory automation.

A caveat is in order: over the past fifty years, automated regulation has received surprisingly scant scholarly attention.[124] Following a brief surge in scholarly interest and litigation over the propriety of fuel adjustment clauses in the mid-twentieth century, regulatory automation has managed to largely avoid the limelight of public discourse. Accordingly, many of the arguments surveyed below were originally crafted in the context of fuel adjustment clauses. In light of their archetypical role for automated regulation, lessons learned over a century of practical experience with fuel adjustment clauses are likely to be of value for regulatory automation more generally. Still, subtle differences in the design and implementation of different types of self-executing regulation may produce widely divergent outcomes, cautioning against the stereotypical application of arguments from one regulatory tool to another.[125]

The arguments raised for and against regulatory automation can be grouped into four categories. The first engages with the efficiency implications of automated regulation.[126] The second category questions the fit of automated regulatory tools with the administrative process.[127] The third type of arguments engages with the political economy of regulatory intervention.[128] The fourth

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[124] *See* Pidot, *supra* note 3, at 168 (lamenting that automated regulation has received "so little attention").

[125] *See* Trigg, *supra* note 7, at 974 (cautioning against too much, if any, stereotyping when it comes to fuel adjustment clauses due to the amount of variation among such clauses); Bennear & Wiener, *supra* note 62, at 5 ("Each instrument for adaptive regulation may pose a different mix of pros and cons.").

[126] *See* discussion *infra* Part III.A.

[127] *See* discussion *infra* Part III.B.

[128] *See* discussion *infra* Part III.C.

class of arguments critically examines the effect of regulatory automation on special interests, using a framework grounded in public choice theory.[129]

After establishing the normative value of automated regulation, this Part probes into its ideal range of operation.[130] Finally, this Part offers a narrowly framed justification for when to use market-based auto-regulations instead of simply placing the regulatory reigns in the market's invisible hand.[131]

A. The Efficiency Implications of Regulatory Automation

Proponents of regulatory automation like to point to efficiency gains as a key virtue of fuel adjustment clauses and similarly automated tools. This argument tends to unfold along two related prongs. The first prong emphasizes the ability of automated regulation to adjust to changing circumstances without the need for active regulatory intervention that often unfolds in the form of lengthy administrative proceedings. Regulatory automation, thus, is said to save critical time and offset otherwise pervasive regulatory lag. This streamlining feature of the regulatory adjustment process features prominently in the literature on the paradigmatic example of fuel adjustment clauses. Richard Pierce, for example, expressed deep concern that any substantial regulatory lag in adjusting utility rates to fuel cost increases could quickly drive an otherwise financially healthy utility into bankruptcy.[132] The very regulators that are, at least partly, responsible for these delays, have openly acknowledged the administrative state's frequent inability to deliver timely responses to changing realities. Writing for the Virginia State Corporation Commission more than half a century ago, Commissioner Catterall quipped:

> The inevitable delay between the happening of an event that entitles a party to legal relief and the date when he gets relief makes it impossible in some kinds of cases for law and equity to do complete justice. Ever since Hamlet mentioned "the law's delay" as one of the things that made him wonder whether it was better "to be or not to be," lawyers and legislators have sought of overcoming so far as possible the time lag in the machinery of justice.[133]

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[129] *See* discussion *infra* Part III.D.

[130] *See* discussion *infra* Part III.E.

[131] *See* discussion *infra* Part III.F.

[132] *See* Pierce, *supra* note 7, at 373; *see also* Foy, *supra* note 7, at 663, 668 (lamenting the complex and time-consuming nature of rate case proceedings).

[133] *Re* Lynchburg Gas Co., 6 P.U.R.3d 33, 35 (Va. State Corp. Comm'n), *additional opinion sub nom. Re* Va. Elec. & Power Co., 7 P.U.R.3d 108 (Va. State Corp. Comm'n 1954), *aff'd sub nom.* City of Norfolk v. Va. Elec. & Power Co., 90 S.E.2d 140 (Va. 1955).

Whatever the veracity of Catterall's claim regarding the motivation behind the Prince of Denmark's famous soliloquy, the concern over regulatory lag underlying the Commissioner's statement still resonates today. Recent commentary highlights the ability of automated regulation to facilitate timely adjustments as new information becomes available.[134]

The second, closely related prong revolves around the costs imposed by the regulatory process itself, beyond those incurred due to the resulting delay. This line of reasoning emphasizes the transaction costs associated with regulatory proceedings, from notice-and-comment rulemaking to adjudication.[135] Writing in defense of the fuel adjustment clause, commentators frequently point to the complexities and expenses associated with otherwise necessary rate case proceedings as a critical benefit of regulatory automation.[136]

The efficiency argument in favor of regulatory automation, based on time and cost savings, is not undisputed. Critics draw attention to the higher upfront costs associated with the crafting of automated regulations. In order to create sensible self-executing adjustment mechanisms, regulatory automation requires more extensive study of the nature and context of a given problem at the outset.[137] This initial due diligence might ask regulators to identify and assess a variety of more or less foreseeable circumstances and to determine ex ante the specific policy response to each of them.[138]

There can be little doubt that automated regulations require greater upfront investment, in terms of both time and effort, than traditional methods of static regulation. Thinking through all possible eventualities and determining the appropriate regulatory responses ahead of time places heightened demands not only on regulators but also on those of their constituents participating in the process. A key premise of automated regulation and other forms of adaptive governance, however, is their enhanced ability to withstand the test of time. As Justin Pidot reminds us, "Static legal rules, sensible when enacted, may become out of date, outliving their usefulness."[139] Designed to adapt to changing circumstances, automated regulations are likely to be longer-lived than their static counterparts who will require periodic manual adjustments to stay relevant. Over time, the transaction costs of these adjustments, along with

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[134] *See, e.g.*, Pidot, *supra* note 3, at 170 (describing how automated regulation "minimizes delays in responding to new information").

[135] *See* 5 U.S.C. § 553.

[136] *See, e.g.*, Foy, *supra* note 7, at 663 ("Few types of legal proceedings are more . . . expensive than the full-blown utility rate case . . . .").

[137] *See* Pidot, *supra* note 3, at 168; *see also* Bennear & Wiener, *supra* note 62, at 28 ("If all of the automated adaptation rules must be designated in the initial rulemaking, this requires good knowledge about the key parameters that will trigger future adaptation, at the time of the original rulemaking.").

[138] *See* Pidot, *supra* note 3, at 170.

[139] *Id.* at 140.

the resulting delays, are likely to dwarf the relatively higher upfront cost required for crafting automated regulations. So long as these regulations are sufficiently long-lived and not abandoned prematurely for political or other extrinsic motivations, the greater initial investment should pay dividends in terms of both time and money, improving the overall efficiency of the regulatory process.

The literature on fuel adjustment clauses has produced another, more targeted, efficiency critique. Some openly tout the virtues of regulatory delay, worrying that the self-adjusting features of automated regulation eliminate the "discipline of regulatory lag."[140] Critics voice concern that the ability to pass along cost increases through automatic rate adjustments reduces the incentive of utilities to prioritize cost minimization and efficiency when choosing among competing technologies and fuels.[141] Relatedly, some worry that a clause's focus on price trends in certain cost inputs, such as fuel, may yield inefficient outcomes by ignoring countervailing developments, such as reductions in other cost inputs, which may significantly alter the utility's overall cost structure.[142] The merits of these critiques notwithstanding, they question not so much the concept of regulatory automation generally, but rather, the specifics of its implementation through fuel adjustment clauses in the utility context. In fact, rather than abandon regulatory automation altogether, the critics themselves are keen to offer suggestions for more rigorous monitoring and other tweaks to improve the efficiency of these clauses without sacrificing the broader benefits of automated regulation.[143]

A final efficiency-related critique concerns the impact of regulatory automation on the predictability of self-adjusting governance tools. In the context of fuel adjustment clauses, for example, skeptics have worried that utility rates' automatic tracking of fuel prices will confuse consumers who "have a right to know [their] utility rate with certainty in advance."[144] Even proponents of adaptive governance concede that the value of regulatory flexibility must be considered against the value of policy stability and predictability.[145] Policy uncertainty has been shown to impose costs, such as when investors ask for

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[140] Leaffer, *supra* note 89, at 233.

[141] *See, e.g.*, Foy, *supra* note 7, at 664, 670; Isaac, *supra* note 85, at 168–69.

[142] *See* Foy, *supra* note 7, at 664; Jones, *supra* note 97, at 542–43 (calling for greater differentiation among different types of costs); Leaffer, *supra* note 89, at 234.

[143] Leaffer, *supra* note 89, at 265.

[144] Foy, *supra* note 7, at 664; *see also Re* Wash. Gas Light Co., 1920D P.U.R. 626, 628 (D.C. P.U.C. 1920); *Re* Pub. Serv. Gas Co., 1920E P.U.R. 395, 397 (N.J. P.U.C. 1920); Jones v. Montpelier & Barre Light & Power Co., 1921D P.U.R. 145, 150 (Vt. P.S.C. 1921).

[145] *See* Bennear & Wiener, *supra* note 62, at 5 (noting Roscoe Pound's tenet that "[l]aw must be stable, and yet it cannot stand still" (quoting ROSCOE POUND, INTERPRETATIONS OF LEGAL HISTORY 1 (1923))).

higher returns to mitigate perceived risks of policy changes that would negatively affect their investment.[146] More generally, perceptions of policy instability can undermine public confidence in, and ultimately, compliance with, regulatory mandates. The same, however, can also be said of policies that prove too sticky and eventually become obsolete for failure to adjust to changing circumstances.[147] Whether the required trade-offs point to static or adaptive governance will likely depend on the regulatory context. Still, the predictability critique of regulatory automation urges policy-makers to craft adaptive governance tools and their self-executing adjustment mechanisms in the most transparent and accessible way possible. Failure to do so may well take away some, if not most, of the purported efficiency gains of automated regulations.[148]

B. Misfits in the Administrative State?

Since their earliest adoption, fuel adjustment clauses have been viewed with suspicion, including by the very agencies to whom their implementation promised the greatest benefits. In 1921, for example, the Pennsylvania Public Service Commission considered such automated regulation to be incompatible "with the spirit and purpose of" regulatory law.[149] A few years later, the Indiana Public Service Commission voiced more specific concerns, questioning its authority to make changes to the regulated rates of its utilities contingent on future events.[150] The Maine Public Utilities Commission, meanwhile, criticized automated fuel adjustment clauses as illegal burden-shifting instruments that transfer the onus of proving the reasonableness of rates "from the utility where it legally belongs, to the Commission where it does not belong."[151] Others, finally, challenged these clauses for violating due process based on the lack of notice and hearing opportunities before each rate increase.[152]

Two pivotal state supreme court decisions have addressed these issues and helped clarify the proper place for automatic fuel adjustment clauses within the administrative state. In *City of Norfolk v. Virginia Electric & Power Co.*,

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[146] *See, e.g.*, Mormann, *supra* note 120, at 705–06 (explaining the value of policy certainty and stability for investment decisions in the context of clean energy technologies).

[147] *See* Bennear & Wiener, *supra* note 62, at 5.

[148] The importance of regulatory predictability and certainty similarly cautions against excessive reliance on machine learning and smart algorithms as replacements for algebra-based adjustment mechanisms. For an intriguing account of the opacity of the algorithms that govern much of our daily lives, see generally FRANK PASQUALE, THE BLACK BOX SOCIETY: THE SECRET ALGORITHMS THAT CONTROL MONEY AND INFORMATION (2015).

[149] Fox v. Pine Grove Elec. Light, Heat & Power Co., 1920B P.U.R. 380, 385 (Pa. P.S.C. 1921).

[150] *See Re* Ind. Serv. Corp., 1930B P.U.R. 278, 281 (Ind. P.S.C. 1930).

[151] *Re* Portland Gas Light Co., 69 P.U.R. (N.S.) 154, 157 (Me. P.U.C. 1947).

[152] *See, e.g.*, City of Chicago v. Ill. Com. Comm'n, 150 N.E.2d 776, 779 (Ill. 1958); City of Norfolk v. Va. Elec. & Power Co., 90 S.E.2d 140, 148 (Va. 1955).

the Supreme Court of Virginia dismissed the plaintiff's due process concerns about an escalator clause for natural gas rates. The court held that "notice is not required on each occasion there is a change in the ratepayers' bills," but rather, only in the event of a "change in the filed schedules which are the underlying bases for the computation of those bills."[153] The court went on to note that aggrieved ratepayers were free to file a complaint with the commission at any time and argue that the imposed rates were "unjust and unreasonable."[154]

The Supreme Court of Virginia also dismissed the plaintiff's challenge to the State Corporation Commission's (SCC) authority to replace its traditional practice of ratemaking through periodic rate case proceedings with an automated fuel adjustment clause.[155] Importantly, the court found no need for express statutory authorization of such clauses, noting that the SCC was free to substitute a mathematical formula for its previous dollars-and-cents rate determinations:

> The proposed escalator clause is nothing more or less than a fixed rule under which future rates to be charged the public are determined. It is simply an addition of a mathematical formula to the filed schedules of the Company under which the rates and charges fluctuate as the wholesale cost of gas to the Company fluctuates. Hence, the resulting rates under the escalator clause are as firmly fixed as if they were stated in terms of money.[156]

Three years later, the Supreme Court of Illinois adopted both the due process and regulatory authority holdings of Virginia's high court in *City of Norfolk* and resolved the last lingering concerns about burden-shifting and the authority of state regulatory commissions to adopt fuel adjustment clauses.[157] In *City of Chicago v. Illinois Commerce Commission*, the Supreme Court of Illinois dismissed the plaintiff's concerns that the fuel adjustment clause would shift the burden of proof away from the utility and onto the commission or consumers. After all, the Illinois Public Utilities Act unequivocally assigns the burden of proof to the utility "[i]n all proceedings before the [Illinois Com-

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[153] *Va. Elec. & Power Co.*, 90 S.E.2d at 149. This widely accepted judicial deference to utility-filed schedules and tariffs, although still in place today, is not without critics. *See* Jim Rossi, *Lowering the Filed Tariff Shield: Judicial Enforcement for a Deregulatory Era*, 56 VAND. L. REV. 1591, 1592 (2003) (warning that "by influencing when courts will hear cases involving regulated firms, the filed tariff doctrine has an alarmingly sweeping scope and effect").

[154] *Va. Elec. & Power Co.*, 90 S.E.2d at 149.

[155] *See id.* at 146.

[156] *Id.* at 148.

[157] *See Ill. Com. Comm'n*, 150 N.E.2d at 779.

merce] Commission."[158] If the Commission has doubts as to the rate produced by the fuel adjustment clause, all it has to do is suspend the resulting rate to require the utility to carry its burden that the suspended rate was, in fact, just and reasonable.

The scholarly literature continues to support the judiciary's deferential approach to utility ratemaking even as restructuring is changing the regulatory landscape.[159] This call for deference is based, in part, on the expectation that judicial review of utility rates by non-expert judges would impose high error costs as well as unduly burdensome constraints on judicial resources.[160] Another argument against excessive judicial oversight rests on the view that the rate-making process includes self-correcting features, as regulators can make up for a rate set too high or too low in one year by commensurate adjustment the following year.[161] Where automated regulation incorporates proactive elements, such as rates based on forecasts of demand, supply, and other relevant factors, similar self-correcting features can, and should, be incorporated into the self-adjusting mechanism to further its function as insurance against forecast errors.[162]

Lingering resentment of fuel adjustment clauses in parts of the literature notwithstanding,[163] the decisions of the Illinois and Virginia high courts firmly established the legitimacy of fuel adjustment clauses. Although the courts' holdings are limited to these clauses, the underlying reasoning offers important guidance for automated regulation more broadly. Due process, for example, does not appear to require notice and hearing opportunities for every single adjustment made by automated regulation. Rather, these requirements need only be satisfied at the time of the self-adjusting regulation's original adoption.[164]

Just as importantly, automated regulation appears not to require express statutory authorization so long as such automation delivers the same type of

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[158] *Id.* at 781 (quoting ILL. REV. STAT. ch. 111 2/3, ¶ 30 (1957)); *see also* Trigg, *supra* note 7, at 971–72 (noting that virtually all state public utility statutes, as well as the Federal Power Act and the National Gas Act, have similar, if not identical, provisions).

[159] *See, e.g.*, Richard J. Pierce, Jr., *Public Utility Regulatory Takings: Should the Judiciary Attempt to Police the Political Institutions?*, 77 GEO. L.J. 2031, 2033 (1989); Susan Rose-Ackerman & Jim Rossi, *Disentangling Deregulatory Takings*, 86 VA. L. REV. 1435, 1454 (2000).

[160] *See* Pierce, *supra* note 159, at 2046.

[161] *See* Rose-Ackerman & Rossi, *supra* note 159, at 1454–55.

[162] *See* discussion *supra* Part I. To incentivize more diligent and comprehensive information sharing by utilities and other regulated entities for the purpose of reducing information asymmetries, such self-correcting mechanisms could be designed to reward more accurate (and penalize inaccurate) projections, based on the differential observed between forecast and actual data.

[163] *See* Leaffer, *supra* note 89, at 237, 265 (describing fuel adjustment clauses as an "aberration in the regulatory process" that "should not become a permanent feature of the regulatory process").

[164] *See* City of Chicago v. Ill. Com. Comm'n, 150 N.E.2d 776, 779–80 (Ill. 1958); City of Norfolk v. Va. Elec. & Power Co., 90 S.E.2d 140, 147–48 (Va. 1955).

work product that the traditional "manual" regulatory process would have produced. Both courts had no problem with the commission's use of a "mathematical formula" to make its rate determinations, given that the eventual work product, utility rates, looked "as if they were stated in terms of money."[165]

Extrapolating beyond the more thoroughly researched, and litigated, domain of fuel adjustment clauses, these insights suggest a surprisingly broad range of applications for automated regulation. Based on the reasoning explicit in the Illinois and Virginia Supreme Court decisions, policy-makers can harness the benefits of regulatory automation in the here and now—without the need for express statutory authorization of such autopilot regulation—across a wide range of circumstances. Whenever a statute calls for regulation by numbers such as the setting of a utility's rates, courts should have no trouble signing off on regulation that supplants static numerical values with a system of pre-determined triggers and mathematical adjustment mechanisms that, ultimately, also yields precise numbers, albeit as the product of a much more dynamic process. Numbers-based regulation is prevalent in a variety of fields. Accordingly, "regulating by math"[166] is already authorized for many key areas of governance, including health care, benefits administration, tax policy, environmental conservation, and pollution abatement, to name but a few.

As a final procedural point, it is worth noting that automated regulation is, on average, better suited than traditional methods of static regulation to accommodate administrative law mandates that agencies explain their decision-making process.[167] A well-developed record, including an explanation of underlying rationale and roads not taken, is intended, and frequently required, to facilitate meaningful judicial review.[168] For purposes of regulatory automation, however, it is more than that—a *conditio sine qua non*. After all, automated regulation logically requires ex ante consideration of a wide swath of potential outcomes, changing circumstances, and regulatory objectives, even in instances where a jurisdiction's administrative laws may impose no such requirement.

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[165] *See Ill. Com. Comm'n*, 150 N.E.2d at 779; *see also Va. Elec. & Power Co.*, 90 S.E.2d at 148.

[166] Use of the term "regulating by math" to describe such numbers-based regulation goes back to a suggestion by Professor Arden Rowell.

[167] *See* Pidot, *supra* note 3, at 170. The same may, however, not be true of automation by algorithm. *See* Ryan Calo & Danielle Keats Citron, *The Automated Administrative State: A Crisis of Legitimacy*, 70 EMORY L.J. (forthcoming 2021) (manuscript at 7, 14–21), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3553590 [https://perma.cc/F8MC-9XW7] (reporting that agencies are increasingly turning to algorithms and other artificially intelligent systems of automation that they do not understand, calling into question the very expertise that affords them judicial deference in their decision-making).

[168] *See, e.g.*, Citizens to Pres. Overton Park, Inc. v. Volpe, 401 U.S. 402, 420 (1971), *abrogated by* Califano v. Sanders, 430 U.S. 99 (1977).

C. The Political Economy of Automated Regulation

Advocates like to point to the political economy benefits of regulatory automation, such as its potential to help overcome political impasse and incentivize stakeholders to share relevant information.[169] Disagreement over the appropriate policy path forward is often based, at least in part, on diverging beliefs and assumptions of what the future holds. Traditional, static approaches to regulation tend to require that policy-makers agree on the regulatory regime that best addresses what appears, at the time, to be the most likely course of events going forward. Reaching a consensus on how that course of events should look can pose serious, if not insurmountable, obstacles for the regulatory process. With its ability to adjust to changing circumstances as they unfold, automated regulation allows policy-makers to incorporate a range of possible futures into their rulemaking product. The need to consider a wide spectrum of eventualities ex ante may be considered a bug to the extent that it raises the upfront costs of regulating.[170] But it is also a feature insofar as different branches of the resulting decision tree can accommodate various, otherwise competing conceptions of the future.[171]

Simply speaking, the resulting narrative is one of "if your version of the future comes true, then the regulation shall work this way, but if my version comes true, then the regulation shall work in another way." In reality, automated regulation is not limited to such binary choices, but rather, can incorporate a variety of competing viewpoints and assumptions about the future. This inclusivity of self-adjusting regulations fosters greater buy-in among stakeholders. Static approaches to regulation tend to resolve polarizing issues through coalition-building up to the minimum required level of support—at the expense of alienating other, not expressly considered, positions. Automated regulation, by contrast, has the potential to foster greater inclusion, growing the number of stakeholders who feel that their viewpoints have been considered, thereby enhancing popular support for the regulatory work product.[172]

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[169] Justin Pidot's work on the political economy of regulatory automation has been especially important. *See* Pidot, *supra* note 3, at 168–71; *see also* Bennear & Wiener, *supra* note 62, at 3 (describing some of the consensus-building features of dynamic models of regulation more generally).

[170] *See supra* notes 137–138 and accompanying text.

[171] *See* Pidot, *supra* note 3, at 170 (noting that automated regulation "can accommodate competing predictions about the future by creating regulatory rules to govern each possibility").

[172] This incorporation of a multitude of potential outcomes differs from the oft-criticized practice of logrolling among policy-makers insofar as the latter frequently involves trading off and lumping together disconnected and potentially divergent policy themes and objectives, whereas automated regulation facilitates the consideration and inclusion of competing views and assumptions about the future as they relate to the stated regulatory goal. For an introduction to logrolling, see James D. Barnett, *Legislative Log-Rolling*, 8 OR. L. REV. 141, 141–48 (1929); see also James B. Kau & Paul H.

To illustrate this dynamic, consider the hypothetical example of a state policy-maker pondering adoption of a new program that would subsidize the deployment of solar power as part of the state's broader suite of policies to combat climate change. Policy-makers across the nation, if not the globe, have considered, and adopted, many such programs in recent years and continue to do so. The debate that accompanies this process almost invariably features a mix of some, if not all, of the following viewpoints and concerns, often claiming empirical and scholarly support.

Viewpoint A: *Solar needs more policy support.* This view, championed by the solar industry as well as many environmental groups, assumes that more is better when it comes to solar policy in order to speed up the transition to a clean, low-carbon energy economy.[173]

Viewpoint B: *Solar needs no (more) policy support.* Bullish solar supporters increasingly take the position that solar power does not require public policy support anymore.[174] The resulting anti-solar policy stance is, not surprisingly, shared by the fossil fuel industry, many utility incumbents and others who have historically opposed pro-solar policies as part of a strategy to protect their vested interests in our fossil-fueled legacy economy.

Viewpoint C: Climate change is not real. Doubters of the reality of climate change, or its anthropogenic nature, also tend to oppose the shift to a low-carbon energy economy powered by solar, wind, and other climate-friendly sources of energy.[175]

Viewpoint D: Climate change is real, but solar power is not the remedy. Even among those genuinely concerned over global climate change, some question the efficacy and efficiency of solar policy as a mitigation strategy. Proponents of this view like to point to the example of Germany, a global lead-

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Rubin, *Self-Interest, Ideology, and Logrolling in Congressional Voting*, 22 J.L. & ECON. 365, 366–67, 380–81 (1979).

[173] *See, e.g.*, Varun Sivaram, Opinion, *Solar Energy Is at Risk*, WASH. POST (Apr. 16, 2018), https://www.washingtonpost.com/news/theworldpost/wp/2018/04/16/solar/ [https://perma.cc/76QZ-EU9D] (arguing that, despite the industry's recent successes, continued policy support for solar is critical to ensure that the transition to a clean, climate-friendly energy economy proceeds without delay).

[174] *See, e.g.*, Roddy Sheer & Doug Moss, *Rooftop Solar Cost Competitive with the Grid in Much of the U.S.*, SCI. AM. (Dec. 1, 2014), https://www.scientificamerican.com/article/rooftop-solar-cost-competitive-with-the-grid-in-much-of-the-u-s/ [https://perma.cc/PL82-DP6J]; *see also* Lincoln L. Davies, *Eulogizing Renewable Energy Policy*, 33 J. LAND USE & ENV'T L. 309, 310 (2018) ("[W]hile the current form of renewable energy policy may not be (quite) dead (just) yet, it is undeniable that the status quo will not remain.").

[175] *See, e.g.*, Lisa Friedman, *'I Don't Know That It's Man-Made,' Trump Says of Climate Change. It Is.*, N.Y. TIMES (Oct. 15, 2018), https://www.nytimes.com/2018/10/15/climate/trump-climate-change-fact-check.html [https://perma.cc/82QP-4GSN] (analyzing President Donald Trump's revised stance toward climate change, which reversed his long-espoused claim that global warming is a hoax but still questioned human responsibility for it).

er in the deployment of solar and other renewables, whose carbon emissions have trended up rather than down.[176]

Viewpoint E: Solar policies are (too) expensive for ratepayers. This view, frequently espoused by ratepayer advocates as well as utility incumbents, assumes that solar power costs ratepayers more than electricity generated from coal, natural gas, and other conventional fuels.[177]

Viewpoint F: Ramping up solar will jeopardize grid reliability. Unlike most conventional power technologies, solar generation requires favorable meteorological conditions, i.e., sunshine, to convert photons into electrons. The resulting output intermittency has led some to question the electric grid's ability to accommodate a growing share of solar, wind, and other intermittent renewables.[178]

Whatever the merits of these six viewpoints, they offer a small yet representative snapshot of the kaleidoscope of competing opinions and concerns that factor into the solar policy-making process. More importantly, they help illustrate the political economy advantages of automated regulation compared to traditional static regulation. After all, it would be nearly impossible to accommodate all of the above in a single, static solar policy regime. Any solar subsidy program following traditional regulatory design would likely meet fierce resistance from all but the solar industry and environmental groups advocating for more pro-solar policy as reflected in *Viewpoint A*. A static program proposal designed to offer a subsidy of, say, \$.02 per kilowatt-hour of solar electricity would be highly unlikely to move forward due to its apparent disregard of the concerns underlying *Viewpoints B* through *F*.

Enter automated regulation. The self-executing adjustment mechanisms of regulatory automation enable policy-makers to plan for and incorporate a wider range of competing viewpoints and assumptions about the future into the

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[176] *See, e.g.*, James Conca, *Why Aren't Renewables Decreasing Germany's Carbon Emissions?*, FORBES (Oct. 10, 2017), https://www.forbes.com/sites/jamesconca/2017/10/10/why-arent-renewables-decreasing-germanys-carbon-emissions/#60a2b29768e1 [https://perma.cc/UY7F-JKQN] (explaining that massive deployment of solar and other renewables has been unable to make up for Germany's continued reliance on high-carbon lignite-fueled power following the country's commitment to phasing out nuclear power).

[177] *See, e.g.*, Tom Johnson, *Rate Counsel Faults New Solar Subsidies for Not Reducing Costs to Utility Customers*, NJ SPOTLIGHT NEWS (Oct. 21, 2019), https://www.njspotlight.com/2019/10/rate-counsel-faults-new-solar-subsidies-for-not-reducing-costs-to-utility-customers/ [https://perma.cc/85QY-PPHT] (reporting discontent over the alleged rate impact of New Jersey's pro-solar policies); *see also* Troy A. Rule, *Solar Energy, Utilities, and Fairness*, 6 SAN DIEGO J. CLIMATE & ENERGY L. 115, 129–42 (2014–2015) (exploring the pervasive use of fairness arguments by utilities opposing net metering and other pro-solar policies).

[178] *See, e.g.*, Mann, *supra* note 123 ("When renewables supply 20 to 30 percent of all electricity, many utility-energy engineers predict, the system will no longer be able to balance supply and demand.").

final regulatory work product. *Viewpoints A* and *B*, for example, can easily be addressed using the kind of automatic subsidy adjustment mechanism found in Oregon's solar incentive program.[179] To do so, the solar subsidy would start out at a very modest level. If *Viewpoint B* were correct that solar power in our hypothetical jurisdiction no longer required significant financial help, then even minimal support should be sufficient to promote the desired deployment. If, on the other hand, *Viewpoint A* proved accurate in its call for more support, then observed deployment would lag behind desired levels. In either scenario, the automatic adjustment mechanism would ensure that a subsidy that proves too high or low at the outset will quickly ramp down or up until actual deployment levels meet the policy-maker's objectives.

Concerns about the reality of climate change, as reflected in *Viewpoint C*, are even easier to address. All it would take is a sunset provision that ends the subsidy program in the event that a reputable source, such as the Intergovernmental Panel on Climate Change,[180] were to conclude that climate change is either not caused by human behavior or not real at all. A similar type of provision could condition the continued availability of the solar subsidy upon measurable reductions in the carbon intensity of our hypothetical jurisdiction's energy mix.[181] If the solar subsidy fails to reduce the carbon intensity after a reasonable period, the program would sunset, prompting the policy-maker to reconsider its choice of tools to combat climate change. Such a provision would address *Viewpoint D*'s doubts regarding the efficacy of solar policy as a mitigation strategy for the greenhouse gas emissions that drive global warming.

Similarly, automated regulation can account for the impact of ratepayer-funded solar subsidies on electricity bills, a concern expressed in *Viewpoint E*, by conditioning the subsidy's availability on annual increases in electricity bills of no more than, say, 5%.[182] A more nuanced approach could further provide for a ramp-down of the subsidy when costs increase by 3% to 5%.

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[179] *See supra* notes 111–117 and accompanying text.

[180] The Intergovernmental Panel on Climate Change (IPCC) is the United Nations' body for assessing the science related to climate change, best known for its periodic reports and forecasts on global warming and sea level rise. *See, e.g.*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, GLOBAL WARMING OF 1.5°C, at v–vi (2018), https://www.ipcc.ch/sr15/ [https://perma.cc/5NKB-XHKJ]. It is worth noting that the choice of reputable source itself may well be controversial given accusations of partiality and bias that doubters of climate change like to raise against the IPCC. *See, e.g.*, Richard Tol, Opinion, *UN Climate Change Expert Reveals Bias in Global Warming Report*, FOX NEWS (May 20, 2014), https://www.foxnews.com/opinion/un-climate-change-expert-reveals-bias-in-global-warming-report [https://perma.cc/TTQ4-HAUP].

[181] Such a provision would, of course, have to control for a variety of other factors that shape the carbon footprint of any economy.

[182] Retail rates of electricity are the product of a variety of factors, including the price of natural gas, transmission, and ancillary services, among other costs incurred by the load-serving entity. Accordingly, a cost-containing sunset provision would have to control for these and other factors.

Finally, automated regulation offers a variety of ways to address *Viewpoint F*'s concerns about the adverse effect that a growing share of solar and other intermittent renewables will have on the stability of the electric grid. The simplest way of doing so would be to endow the solar program with a sunset provision that terminates the subsidy in case average outage times—excluding outages caused by severe weather and other force majeure events[183]—in our hypothetical jurisdiction increase by a set threshold percentage. A more gradual approach could provide for an inverse correlation between the solar subsidy level and the number of interventions required of the grid operator to maintain the network's delicate balance. Assuming that intermittent solar power does, in fact, challenge grid stability, such a regime would provide for gradual reductions in subsidy—and thus, deployment levels—before these challenges escalate into actual outages.

To be clear, the work product of our hypothetical exercise in regulatory automation will be significantly more complex than its static counterpart. After all, the latter might make do with a one-liner denoting the subsidy value and eligible technologies. Such complexity appears a small price to pay, however, considering the ability of automated regulation to address and incorporate a wide array of competing viewpoints and concerns, as demonstrated above.

Crucially, regulatory automation is more than just a catalyst for consensus. It also provides strong incentives for stakeholders to share relevant information.[184] In the traditional static regulatory process, critics often have little motivation to offer more than a general explanation for their opposition to a project. If the policy-maker is making what appears to be a binary choice to move forward or not, there may be little benefit in divulging more information than strictly necessary to stall the project. Thus, representatives of *Viewpoints B*, *C*, *D*, *E*, and *F* might do little more than voice their general opposition to a solar subsidy, leaving the policy-maker in the dark as to the diverse concerns motivating that opposition. With its ability to add greater nuance to regulatory method and outcome, automated regulation rewards stakeholders willing to elaborate on their concerns. Once they realize that a policy-maker has far more than just two diametrically opposed options—to proceed or not—to choose from, stakeholders appreciate that offering up additional information increases the chances that their input will actually make a difference in the policy-making process and result. Only by drawing the policy-maker's attention to the alleged correlation between solar deployment and grid stability can representatives of *Viewpoint F* hope to

[183] Most jurisdictions measure their electrical grid's stability using the System Average Interruption Duration Index that denotes the average service interruption time to consumers in the low- and medium-voltage grid as a result of causes other than extreme weather and other major events. *See* Mormann et al., *supra* note 80, at 71.

[184] *See* Pidot, *supra* note 3, at 169–70.

see their underlying concerns addressed. The same is true, of course, for the various doubts and concerns espoused by *Viewpoints B* through *E*.

Thus far, I have explored the political economy benefits of regulatory automation primarily from the ex ante perspective of a polity pondering adoption of a new program. Many of these benefits may persist well past the adoption stage to help enhance the legitimacy and, with it, longevity of automated regulation. From an ex post perspective, some of the most ambitious and daring regulatory endeavors of our time have begun to lose their popular allure and political support soon after implementation. Consider the health care reforms brought about by the 2010 Patient Protection and Affordable Care Act, better known by its popular nickname Obamacare.[185] When implementation of the Act began to reveal the full scope of its dramatic changes to the U.S. health care system, approval rates among Americans declined from fifty percent in mid-2010 to an all-time low of thirty-three percent by November 2013.[186] When asked to put their money where their mouth, or rather their ballot, was, many voters apparently felt buyer's remorse, making the Affordable Care Act an easy target during the 2016 presidential campaign.[187]

This kind of popular backlash is not uncommon, especially in the context of policies that push the electorate's pressure points, such as by raising the cost of living or encroaching upon personal freedoms. The Affordable Care Act may have survived, for now.[188] But other policies have been less lucky. When the going gets tough and lofty policy goals translate to real-world costs for the

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[185] *See* Patient Protection and Affordable Care Act of 2010, Pub. L. 111-148, 124 Stat. 119 (codified as amended in scattered sections of 42 U.S.C.). For a snapshot of the vast literature on the Affordable Care Act, see generally, for example, Tom Baker, *Health Insurance, Risk, and Responsibility After the Patient Protection and Affordable Care Act*, 159 U. PA. L. REV. 1577 (2011) (exploring the Affordable Care Act as a new social contract that distributes risk and places an emphasis on personal responsibility in health care decisions); Erwin Chemerinsky, *Political Ideology and Constitutional Decisionmaking: The Coming Example of the Affordable Care Act*, 75 L. & CONTEMP. PROBS. 1 (2012) (arguing that the Affordable Care Act is clearly constitutional but that political ideology, rather than constitutional doctrine, will motivate any decision by the U.S. Supreme Court to uphold the law); Martha Minow, *Affordable Convergence: "Reasonable Interpretation" and the Affordable Care Act*, 126 HARV. L. REV. 117 (2012) (providing an overview of the debate over the Affordable Care Act and asserting that Chief Justice John Roberts's decision to uphold the law highlights the Court's continued commitment to legal, rather than ideological, decision-making).

[186] *See KFF Health Tracking Poll: The Public's Views on the ACA*, KAISER FAM. FOUND., https://www.kff.org/interactive/kff-health-tracking-poll-the-publics-views-on-the-aca/#?response=Favorable—Unfavorable&aRange=all [https://perma.cc/HYW6-8AWK] (Dec. 18, 2020).

[187] Ironically, approval rates for the Affordable Care Act have been on the rise since, reaching a high of 54% in early 2018 and remaining mostly above the 50% mark after that. *See id.*

[188] *But see* Texas v. United States, 352 F. Supp. 3d 665, 680–83, 689–90 (N.D. Tex. 2018), *aff'd in part, rev'd in part*, 945 F.3d 355 (5th Cir. 2019), *cert. granted*, California v. Texas, 140 S. Ct. 1262 (2020) (reviewing the constitutionality of the Affordable Care Act's individual mandate as amended by the 2017 Tax Cuts and Jobs Act).

electorate, regulatory backtracking turns into temptation.[189] Here, too, automated regulation's need for greater anticipation of possible outcomes and consideration of potential alternatives may prove to be a feature rather than a bug. After all, constituents and politicians alike have a much harder time claiming that the growing pains associated with new policy were unexpected, or even unintended, when the latter were expressly incorporated into the regulation's self-executing adjustment mechanisms. The same logic would raise the political costs of undoing a policy for reasons clearly contemplated by its adopting polity. To be clear, no policy-maker can fully bind its successor. But the consensus-building and transparency-fostering properties of regulatory automation can, at a minimum, raise the political price of dismantling policies that were adopted with widespread popular support.

D. Public Choice, Special Interests, and the Risk of Gaming

In 1951, Nobel Laureate Kenneth Arrow's seminal work *Social Choice and Individual Values*[190] laid the foundation for a new field of social science that would go on to become a dominant theme in contemporary legal scholarship.[191] Drawing primarily from the field of microeconomics, public choice theory treats regulatory decision-making as an analogue to market decision-making.[192] This analogy posits that legislative, regulatory, and electoral institutions form an economy wherein various actors, such as individual citizens, interest groups, and policy-makers, exchange regulatory goods based on the same market principles that determine the demand and supply of ordinary economic goods.[193] Today, public choice theory informs scholarly analysis of judicial and administrative decision-making across a wide range of substantive contexts.[194] A central tenet of the public choice narrative is that organized

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[189] Consider, for example, the ignominious end of Australia's 2011 carbon pricing scheme after only a few short years. *See* Lenore Taylor, *Australia Kills Off Carbon Tax*, THE GUARDIAN (July 16, 2014), https://www.theguardian.com/environment/2014/jul/17/australia-kills-off-carbon-tax [https://perma.cc/SWR4-QM3T].

[190] *See generally* KENNETH J. ARROW, SOCIAL CHOICE AND INDIVIDUAL VALUES (1951).

[191] *See, e.g.*, Edward L. Rubin, *Public Choice in Practice and Theory*, 81 CALIF. L. REV. 1657, 1657 (1993) ("While its origins lie in microeconomics, public choice has clearly become one of the dominant themes in contemporary legal scholarship.").

[192] *See* Steven P. Croley, *Theories of Regulation: Incorporating the Administrative Process*, 98 COLUM. L. REV. 1, 34–56 (1998) (offering an overview and critique of public choice theory).

[193] *See, e.g.*, Richard A. Posner, *Theories of Economic Regulation*, 5 BELL J. ECON. & MGMT. SCI. 335, 335–40 (1974); George J. Stigler, *The Theory of Economic Regulation*, 2 BELL J. ECON. & MGMT. SCI. 3, 3–6 (1971).

[194] *See, e.g.*, William N. Eskridge, Jr., *Politics Without Romance: Implications of Public Choice Theory for Statutory Interpretation*, 74 VA. L. REV. 275, 276–79 (1988); Paul J. Larkin, Jr., *Public Choice Theory and Overcriminalization*, 36 HARV. J.L. & PUB. POL'Y 715, 722–23 (2013); Daniel H. Lowenstein, *Campaign Spending and Ballot Propositions: Recent Experience, Public Choice Theory*

groups enjoy greater influence in the regulatory marketplace than individual voters, as the group's greater aggregate benefits from a given regulatory good enable it to outbid individual competitors.[195]

Recent scholarship suggests that automated regulation may have a countervailing effect on the dominance of well-organized special interest groups in the regulatory marketplace.[196] Where static regulation produces certain and easy-to-determine benefits and burdens, the argument goes, the flexibility of self-adjusting regulatory regimes makes it significantly harder to predict the ultimate outcome, and hence, assess the regime's relative value for specific interest groups.[197]

Perennial optimists might go one step further yet and compare the anti-lobbying effect of regulatory automation to that of John Rawls's famous "veil of ignorance." In his foundational work, *A Theory of Justice*, Rawls postulates the need to eliminate special interests that put stakeholders at odds with one another and tempt them to pursue their own advantage.[198] To do so, he envisions placing parties behind a veil of ignorance that prevents them from knowing how various options will affect their own interests, forcing them to make decisions exclusively on the basis of general, impartial considerations. In his thought experiment, Rawls's veil deprives parties of all knowledge related to their place in society, class, or social status, their distribution of assets and abilities, their intelligence, and other critical properties.[199] Regulatory automation, of course, cannot change our awareness of our place in society. With its built-in flexibility and wide range of potential adjustments, however, automated regulation leaves constituents guessing as to the ultimate effect of said regulation on their own interests. This clouded outlook and the resulting uncertainty should, at a minimum, reduce the expectation value of any lobbying or other intervention contemplated by special interest groups. If a special interest

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and the First Amendment, 29 UCLA L. REV. 505, 511–13 (1982); Jonathan R. Macey, *Public Choice: The Theory of the Firm and the Theory of Market Exchange*, 74 CORNELL L. REV. 43, 43–45 (1988); Thomas W. Merrill, *Does Public Choice Theory Justify Judicial Activism After All?*, 21 HARV. J.L. & PUB. POL'Y 219, 219–20 (1997); Matthew L. Spitzer, *Multicriteria Choice Processes: An Application of Public Choice Theory to* Bakke*, the FCC, and the Courts*, 88 YALE L.J. 717, 717–18 (1979). For a comprehensive account of the widespread adoption of public choice theory by legal scholarship, see generally DANIEL A. FARBER & PHILIP P. FRICKEY, LAW AND PUBLIC CHOICE: A CRITICAL INTRODUCTION (1991) (providing a survey of public choice theory as it relates to understanding the legislative process and its influence on legal doctrine and studies).

[195] *See, e.g.*, Croley, *supra* note 192, at 39 ("[T]he regulatory market works, on the whole, to the advantage of organized groups with narrow interests.").

[196] *See* Pidot, *supra* note 3, at 171.

[197] *See id.* ("[I]t may be unpredictable when initial rules are established which parties will be most affected by future restrictions . . . .").

[198] *See* JOHN RAWLS, A THEORY OF JUSTICE 118 (1999).

[199] *Id.*

group's desired outcome is but one of many possible outcomes that self-adjusting regulation could produce, the resulting uncertainty may lower incentives for lobbying.

The intuitive appeal of such an anti-lobbying effect of regulatory automation notwithstanding, several factors caution against too much optimism. First, even automated regulation is subject to some degree of default setting in form of the regulatory outcome that will come to pass if none of the self-executing adjustment mechanisms are triggered. Interest groups may, therefore, have a strong incentive to ensure that this default option advances their special interests. Once the default option suits their needs, the same groups may use their clout to reduce the likelihood of deviation from said default, such as by conditioning any auto-adjustments on increasingly improbable trigger events.[200] In the extreme, such interventions could make automated regulation prone to the same status quo bias frequently found and criticized in traditional, static types of regulation.[201]

A second concern relates to the costs that interest groups incur when advocating for a specific self-serving outcome. The uncertainties associated with self-adjusting regulation may reduce the likelihood of a specific outcome, and therefore, diminish the expectation value of related lobbying or other interventions. But they also reduce the saliency and, with it, the political capital required to advocate for what an objective observer might describe as but one potential outcome among many.[202] Regulatory automation's reliance on input from a wide range of stakeholders[203] may further blur the line between participation in the regulatory process and lobbying. In the end, these and other traits of regulatory automation may reduce the advocacy costs of interest groups to a point where they are low enough to promise a positive return on investment even when measured against less-than-certain regulatory benefits.

Finally, caution is warranted insofar as automated regulation may provide opportunities for interest groups to influence the regulatory outcome well beyond the rulemaking and adoption stages, such as through actions that help trigger pre-determined automatic adjustments in their favor. To minimize the risk of such gaming, care must be taken to condition adjustments upon exogeneous factors and events that lie beyond the control of individual interest groups and even, where possible, the concerted actions of multiple groups. Such gam-

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[200] *See, e.g.*, Bradley C. Karkkainen, *Adaptive Ecosystem Management and Regulatory Penalty Defaults: Toward a Bounded Pragmatism*, 87 MINN. L. REV. 943, 965–66 (2003) (noting the important role played by default rules in creating incentives for bargaining and cooperation).

[201] For a thoughtful inquiry into the potential negative—and positive—effects of status quo bias, see Kysar, *supra* note 68, at 815–18.

[202] For a discussion of the relative saliency and political cost of special interests, comparing tax expenditures to direct subsidies, see Mormann, *supra* note 48, at 337.

[203] *See* discussion *supra* Part III.C.

ing-resistant regulatory design will be relatively easy to the extent that time-based triggers are being used.[204] Market-based triggers present greater risk, albeit less so when they are anchored in competitive markets where no one firm or group of firms is in a position to exercise market power.[205] Still, policy-makers would do well to apply care and keep an eye on pending antitrust proceedings in choosing the triggers for automatic adjustments, especially when operating in areas of the economy such as energy, where the transition to competitive markets is a work in progress.[206]

E. Beyond Known Unknowns and Foreseeable Uncertainty

> *[A]s we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know.*[207]
>
> —Donald H. Rumsfeld

When asked about weapons of mass destruction in Iraq, then-Secretary of Defense Donald Rumsfeld famously distinguished between "known unknowns" and "unknown unknowns," based on the awareness we have of our own ignorance. In his thoughtful musings over varieties of uncertainty, Justin Pidot draws a similar distinction between foreseeable and unforeseeable uncertainty.[208] To Pidot, only "known unknowns," that is to say, instances of foreseeable uncertainty—defined as an identifiable range of potential future circumstances—lend themselves to regulatory automation. Unforeseeable uncertainty, he posits, cannot be addressed through the self-executing adjustment mechanisms of automated regulation, but rather, requires human-led regulatory intervention as novel, unexpected circumstances materialize.[209]

Although Pidot deserves praise for his thoughtful contribution to expanding our typology of uncertainty, his conclusion as to the limitations of automated regulation is less convincing. Pidot presumes that automated regulation requires ex ante knowledge and consideration of specific uncertainties in order to accommodate them through self-executing adjustment mechanisms. That is

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[204] *See* discussion *supra* Part II.A.

[205] *See* discussion *supra* Part II.B.

[206] *See, e.g.*, FERC v. Elec. Power Supply Ass'n, 136 S. Ct. 760, 769 (2016) ("[T]he wholesale electricity market lacks the self-correcting mechanism of other markets.").

[207] *See* News Transcript, U.S. Dep't of Def., DoD News Briefing–Secretary Rumsfeld and Gen. Myers (Feb. 12, 2002) (statement of Secretary of Defense Donald Rumsfeld), https://archive.defense.gov/Transcripts/Transcript.aspx?TranscriptID=2636 [https://perma.cc/V75X-6AUR].

[208] *See* Pidot, *supra* note 3, at 177–80.

[209] *Id.* at 180.

not so, at least to the extent that unforeseeable uncertainties—the Rumsfeldian "unknown unknowns"—are captured among the metrics used to trigger automatic adjustments.

To illustrate this dynamic, consider the earlier example of a solar subsidy.[210] Following the real-world examples of California and Oregon,[211] our hypothetical jurisdiction pegged the value of its subsidy to the pace of solar deployment. If the build-out of solar generation infrastructure proceeds at the desired pace, then the subsidy value remains stable. If progress is slower (or faster) than intended, the subsidy automatically ramps up (or down) according to pre-determined triggers. When policy-makers incorporate these kinds of self-executing adjustment mechanisms, they are primarily concerned that, without them, their programs may not keep up with the breathtaking pace of technology learning that continues to drive down the cost of solar and other emerging clean energy technologies.[212] The intuitive reaction, then, might be to peg the subsidy value to the cost of solar panels, inverters, and other critical hardware. To do so, however, would ignore the reality that, at this point, hardware expenditures account for less than one-third of a system's overall cost.[213] Tethering auto-adjustments to actual deployment as opposed to hardware components enables automated regulation to capture a much broader range of developments that may affect a policy's success. By choosing a metric that tracks the policy's ultimate objective, this outcome-oriented trigger design casts a wide enough net to capture not only "known unknowns," such as the precise pace of hardware cost improvements, but also "unknown unknowns" or types of uncertainty that were unforeseeable at the time of adoption.

In mid-2016, continued declines in the production costs for solar hardware were foreseeable, even if the precise rate was uncertain. But few could have foreseen the thirty percent tariff on imported solar cells and modules that President Donald Trump would approve under Section 201 of the Trade Act of 1974[214] just a year and a half later.[215] In the summer of 2015, Mr. Trump

[210] *See* discussion *supra* Part III.C.

[211] *See supra* notes 111–117 and accompanying text.

[212] *See, e.g.*, KRISTEN ARDANI ET AL., NAT'L RENEWABLE ENERGY LAB'Y, COST-REDUCTION ROADMAP FOR RESIDENTIAL SOLAR PHOTOVOLTAICS (PV), 2017–2030, at vi (2018), https://www.nrel.gov/docs/fy18osti/70748.pdf [https://perma.cc/S43D-EZRV] ("The installed cost of solar photovoltaics (PV) has fallen rapidly in recent years and is expected to continue declining in the future."); *see also supra* note 106 and accompanying text (discussing the fallout from Spain and Germany's failure to adjust their solar subsidies to technology learning and rapid cost improvements).

[213] *See* FU ET AL., *supra* note 119, at vi, viii (reporting that soft costs account for 68% of overall costs in residential solar projects).

[214] *See* 19 U.S.C. § 2251.

[215] *See* Press Release, Off. of the U.S. Trade Representative, President Trump Approves Relief for U.S. Washing Machine and Solar Cell Manufacturers (Jan. 22, 2018), https://ustr.gov/about-

trailed Hillary Clinton by nearly twenty percentage points in the polls.[216] Moreover, the "solar trade war[s]"[217] seemed all but resolved following the World Trade Organization's ruling against U.S. countervailing tariffs imposed on Chinese solar hardware.[218] And, yet, against all odds, Donald Trump not only won the presidency, but also wasted little time in ending whatever trade *détente* there might have been between the United States and China. His tariff proved highly disruptive, causing the solar industry to miss deployment projections for the first time in years and costing more than 3,000 Americans their jobs.[219] In other words, it would almost certainly have affected the solar build-out in our hypothetical jurisdiction.

These developments were hard, if not impossible, to foresee for even the most clairvoyant policy-maker back in 2016. Nevertheless, our hypothetical solar program would have no difficulty coming up with the appropriate, automated response. That is because the Trump administration's tariffs would register as a slowdown in deployment and thus be captured by the pre-determined triggers for adaptation. Agnostic as to the precise cause for lagging deployment, the automated solar regulation would simply ratchet up the subsidy level in order to bring the program back on track. The same self-executing adjustment could address industry-wide strikes, geopolitical tensions reducing the supply of required rare earth elements and other essential materials, or a global financial crisis raising the cost of capital for developers.

The lesson here is fairly straightforward. Contrary to scholarly skepticism, regulatory automation can provide effective, and more importantly, time-

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us/policy-offices/press-office/press-releases/2018/january/president-trump-approves-relief-us [https://perma.cc/GR4Z-RGZ8].

[216] *General Election: Trump vs. Clinton—RCP Electoral Map*, REALCLEARPOLITICS, https://www.realclearpolitics.com/epolls/2016/president/us/general_election_trump_vs_clinton-5491.html [https://perma.cc/3MLR-HGX5] (click "July 1, 2015" on the line graph to view the underlying polling average data).

[217] *See* Emily Holden, *U.S. Setting Stage for Solar Trade War with China*, POLITICO (Dec. 15, 2017), https://www.politico.com/story/2017/12/15/trump-solar-power-china-trade-barriers-230854 [https://perma.cc/7UT5-5LXG].

[218] *See* Panel Report, *United States—Countervailing Duty Measures on Certain Products from China*, WTO Doc. WT/DS437/R (July 14, 2014), https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/WT/DS/437R.pdf&Open=True [https://perma.cc/YW7K-S8VZ].

[219] *See* Tony Clifford, *Section 201, the Sequel: What Will Come of the Solar Tariffs?*, PV MAG. (Aug. 28, 2019), https://pv-magazine-usa.com/2019/08/28/section-201-the-sequel-what-will-come-of-the-solar-tariffs/ [https://perma.cc/7FQ4-FWG8] (criticizing the tariffs for underdelivering on the promise of a renaissance in domestic solar manufacturing). For an even more dramatic, albeit potentially biased account, see SOLAR ENERGY INDUS. ASS'N, *The Adverse Impact of Section 201 Tariffs: Lost Jobs, Lost Deployment and Lost Investments* (Dec. 2019), https://www.seia.org/research-resources/adverse-impact-section-201-tariffs [https://perma.cc/T8QA-J4NH] (quantifying the Section 201 Tariffs' negative impact on the economy at 62,000 fewer U.S. jobs, 10.5 gigawatts of lost solar deployment, and $19 billion in lost investment from 2017 through 2021).

ly answers to even the most improbable and unforeseeable events. The secret lies in choosing the right metric to trigger self-executing adjustments. Simply speaking, the better a metric tracks the desired outcome, the more likely it is to capture all relevant inputs into the value chain, including Donald Rumsfeld's famous "unknown unknowns." As our hypothetical solar program demonstrates, using observed deployment levels—the ultimate indicator of policy efficacy—as the relevant trigger metric, casts a wide enough net for automated regulation to address both foreseeable and unforeseeable uncertainty.

Caution is warranted, however. The fact that pre-determined auto-adjustment triggers can provide an effective response even to unforeseeable developments does not mean that the resulting adjustment necessarily represents the optimal policy response. In our solar subsidy hypothetical, the pre-programmed response to lagging deployment is to throw money at the problem. That may be an effective and possibly efficient remedy for the cost increases caused by Trumpian tariffs but could well prove an inefficient answer to lag produced by unduly burdensome permitting procedures or other soft-cost factors.[220] Policy-makers would do well, therefore, not to let the self-executing adjustments of their automated regulations operate completely unmonitored. Even where those adjustments manage to move a policy back on track toward achieving its stated objective, the chosen path may raise other concerns, such as those related to efficiency or equity.

F. Why Not Just Leave It to the Market?

This Article distinguishes between time-based and market-based triggers for self-executing adjustments to automated regulation. I have presented market-based metrics as the more granular, more sophisticated approach.[221] It is probably no coincidence that the paradigmatic example of fuel adjustment clauses relies on the market price of a utility's fuel inputs to trigger automatic escalations (or reductions) of its rates. All of this invites a simple question: why try to craft complex automated regulation to track market developments when policy-makers could simply rely on the market itself?

In his seminal work on the efficient market hypothesis, Nobel Laureate Eugene Fama tested, and ultimately found strong empirical support for, the old adage that prices in efficient markets reflect available information.[222] More

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[220] For a detailed discussion of these and other soft-cost factors along with potential policy remedies, see Mormann, *supra* note 120, at 704–24.

[221] *See* discussion *supra* Part II.B.

[222] *See, e.g.*, Eugene F. Fama, *Efficient Capital Markets: A Review of Theory and Empirical Work*, 25 J. FIN. 383, 384, 416 (1970) [hereinafter Fama, *Efficient Capital Markets I*]; *see also* Eugene F. Fama, *Efficient Capital Markets: II*, 46 J. FIN. 1575, 1576 (1991) (remarking that "past research on

recent scholarship in behavioral economics has added the caveat that market prices reflect not only available information, but also the trading practices of market participants who do not always act rationally.[223] Still, few would question the ability of well-organized, competitive markets to serve as conduits and repositories for relevant information. Policy-makers pondering regulatory automation as a strategy for keeping their policies current in a fast-changing economic environment would, therefore, do well to also consider a directly market-based approach.[224] As they do so, however, they should start by asking themselves whether the market in question can actually serve all of their policy interests and objectives.

From a functional perspective, the efficient market hypothesis assumes the existence of competitive markets free from the exercise of market power, information asymmetries, and other market failures.[225] In the real world, none of these characteristics can be taken for granted. This is especially true for those areas of the economy, such as telecommunications, energy, or air travel, that have only recently restructured and begun the long and difficult transition from regulation of service and price to competitive markets.[226] Pervasive anticompetitive conduct in the emerging platform market economy further cautions against placing too much faith in the universal ability of markets to deliver on the efficient market hypothesis's promise of prices as the product of information aggregation.[227]

Even where fully competitive markets exist free from market failures, they may not meet all the objectives a policy-maker seeks to achieve. By design, markets seek to facilitate the most efficient allocation of resources, plac-

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market efficiency is among the most successful in empirical economics, with good prospects to remain so in the future").

[223] *See generally, e.g.*, Nicholas Barberis & Richard Thaler, *A Survey of Behavioral Finance*, *in* HANDBOOK OF THE ECONOMICS OF FINANCE 1053 (George M. Constantinides et al. eds., 2003).

[224] The Acid Rain Trading Program's cap-and-trade scheme to reduce sulfur dioxide and nitrogen oxide emissions offers an illustrative example of such a market-based approach. *See* 42 U.S.C. § 7651.

[225] *See* Fama, *Efficient Capital Markets I*, *supra* note 222, at 387 (discussing the various market conditions required for market prices to accurately reflect relevant information).

[226] *See, e.g.*, Severin Borenstein & James Bushnell, *Electricity Restructuring: Deregulation or Reregulation*, 23 REGUL. 46, 49 (2000) (noting, for example, the greater "ability of firms with modest market shares to exercise market power" in the electric industry).

[227] *See, e.g.*, Lina M. Khan, *The Separation of Platforms and Commerce*, 119 COLUM. L. REV. 973, 1008–15 (2019) (offering a powerful critique of the conflicts of interest inherent in online platform providers and the businesses that depend on them, including strong incentives for anticompetitive conduct); Lina M. Khan & David E. Pozen, *A Skeptical View of Information Fiduciaries*, 133 HARV. L. REV. 497, 502–20 (2019) (expressing a concern that fiduciary duties imposed on online platform providers will not be sufficient to remedy broader structural market concerns).

ing goods and services in the hands of those who value them the most.[228] This efficiency-optimizing function may align with the stated objective of budget appropriations and other hard-and-fast economic policies. But it is unlikely to address the multitude of competing interests—from political earmarking to distributional equity—that factor into the deal-making required to reach political consensus in an increasingly partisan environment.[229] Place-based tax incentive programs, for example, are intended to promote economic development. Yet, they are not designed to deliver the greatest bang for the taxpayers' buck, such as by targeting those areas that promise the highest productivity.[230] Instead, these tax incentives are commonly aimed at particularly poor parts of the country to help elevate the local citizenry out of poverty. The underlying prioritization of equity and distributional fairness over efficiency runs counter to the very foundation of market economics. Policy-makers would, therefore, be badly misguided if they thought their equity objectives could be served by turning the allocation of place-based tax incentives over to the market's invisible hand.

Climate change provides another illustration of both the potential and limitations of markets to address pressing policy needs. Traditional regulatory regimes and more market-based policies have long vied for dominance in the emerging low-carbon economy.[231] Economic theory suggests that putting a price on greenhouse gas emissions is the most efficient policy to reduce humanity's carbon footprint, leaving the market to figure out the best mix of abatement strategies and technologies.[232] Recent scholarship, however, raises

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[228] *See, e.g.*, Fama, *Efficient Capital Markets I*, *supra* note 222, at 383 ("The primary role of the capital market is allocation of ownership of the economy's capital stock." (emphasis omitted)).

[229] *See, e.g.*, SARAH A. BINDER, MINORITY RIGHTS, MAJORITY RULE: PARTISANSHIP AND THE DEVELOPMENT OF CONGRESS 4–6, 9 (1997); DOUGLAS DION, TURNING THE LEGISLATIVE THUMBSCREW: MINORITY RIGHTS AND PROCEDURAL CHANGE IN LEGISLATIVE POLITICS 15 (1997) (noting the influence of partisanship as a driver of procedural change).

[230] For a thoughtful account and critique of place-based tax incentive programs, see Michelle D. Layser, *The Pro-Gentrification Origins of Place-Based Investment Tax Incentives and a Path Toward Community Oriented Reform*, 2019 WIS. L. REV. 745, 771–98.

[231] *See* Mormann, *supra* note 110, at 9.

[232] *See generally* NICHOLAS STERN, THE ECONOMICS OF CLIMATE CHANGE: THE STERN REVIEW 394 (2007) ("In the absence of any other market failures, introducing a fully credible carbon price path for applying over the whole time horizon relevant for investment would theoretically be enough to encourage suitable technologies to develop."); Dominique Finon, *Pros and Cons of Alternative Policies Aimed at Promoting Renewables*, 12 EIB PAPERS 110, 112 (2007), https://www.eib.org/attachments/efs/eibpapers/eibpapers_2007_v12_n02_en.pdf [https://perma.cc/4A54-PK4R] ("[I]t is nonetheless pertinent to ask whether there is a need to promote renewables in situations where economic policies internalise the environmental externalities of polluting energy technologies."); Carolyn Fischer & Richard G. Newell, *Environmental and Technology Policies for Climate Mitigation*, 55 J. ENV'T ECON. & MGMT. 142, 143 (2008) ("[P]olicies that create incentives for fossil-fueled generators to reduce emissions intensity . . . perform better than those that rely on incentives for renewable energy producers alone."); Adam B. Jaffe et al., *A Tale of Two Market Failures: Technology and Environmental Policy*, 54 ECOLOGICAL ECON. 164, 165 (2005) ("[T]here is little dispute among economists

important questions as to the propriety of relying primarily on markets to mitigate global climate change and drive the transition to a low-carbon energy future.[233] This market skepticism is based on the empirically supported argument that regulatory approaches are better suited to facilitate long-term planning and engage the public in the deliberative process required to balance the many competing values and interests involved.[234] Once again, efficiency optimization alone may not produce the desired policy outcome.

It is worth noting, finally, that parts of our society have yet to accept markets as appropriate instruments for determining the valuation and allocation of resources. When it comes to the allocation of water rights, for example, the United States is deeply divided as to the proper role for markets. The same debate can be traced in the legal literature.[235] Proponents argue that markets are bound to outperform regulatory regimes.[236] Opponents take the position that a resource as precious and essential as water should never be subjected to the rule of markets.[237] Similar skepticism toward commoditization and market governance is evident in other critical areas of the economy, such as electricity[238] and healthcare.[239]

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that flexible, incentive-oriented policy approaches are more likely to foster low-cost compliance paths than prescriptive regulatory approaches."); David Klenert et al., *Making Carbon Pricing Work for Citizens*, 8 NATURE CLIMATE CHANGE 669, 669 (2018) ("Economic analyses have long recommended carbon pricing as an indispensable strategy for efficiently reducing GHG emissions and tackling climate change.").

[233] *See* Alice Kaswan, *Energy, Governance, and Market Mechanisms*, 72 U. MIA. L. REV. 476, 476–77 (2018).

[234] *See id.* at 527–54.

[235] For a thoughtful account of the opposing viewpoints, see Vanessa Casado Perez, *Liquid Business*, 47 FLA. ST. U. L. REV. 201, 202–09 (2019).

[236] *See, e.g.*, RODNEY T. SMITH, TRADING WATER: AN ECONOMIC AND LEGAL FRAMEWORK FOR WATER MARKETING 12 (1988); James L. Huffman, *Markets, Regulation, and Environmental Protection*, 55 MONT. L. REV. 425, 427 (1994); James L. Huffman, *Water Marketing in Western Prior Appropriation States: A Model for the East*, 21 GA. ST. U. L. REV. 429, 432 (2004); Andrew P. Morriss, *Real People, Real Resources, and Real Choices: The Case for Market Valuation of Water*, 38 TEX. TECH L. REV. 973, 983 (2006); Mateen Thobani, *Tradable Property Rights to Water: How to Improve Water Use and Resolve Water Conflicts*, VIEWPOINT (The World Bank, Private Sector Dev. Dep't, Washington, D.C.), Feb.1995, at 1.

[237] *See, e.g.*, Michael C. Blumm, *The Fallacies of Free Market Environmentalism*, 15 HARV. J.L. & PUB. POL'Y 371, 375 (1992); Joseph W. Dellapenna, *The Importance of Getting Names Right: The Myth of Markets for Water*, 25 WM. & MARY ENV'T L. & POL'Y REV. 317, 320–21 (2000); Norman W. Spaulding III, *Commodification and Its Discontents: Environmentalism and the Promise of Market Incentives*, 16 STAN. ENV'T L.J. 293, 308–17 (1997).

[238] *See, e.g.*, Peter Cramton, *Electricity Market Design*, 33 OXFORD REV. ECON. POL'Y 589, 590 (2017) (noting that electricity markets are the product of a regulatory process because electricity is still viewed as an essential service).

[239] For a thoughtful discussion of the tension between perceptions of "[h]ealthcare as a [r]ight" and free-market capitalism in healthcare, see, for example, N. GREGORY MANKIW, THE ECONOMICS OF HEALTHCARE 6 (2017), https://scholar.harvard.edu/files/mankiw/files/economics_of_healthcare.pdf [https://perma.cc/2QN9-5NYX].

This Section is not intended to suggest a wholesale dismissal of policymakers' reliance on markets in lieu of automated regulation with market-based triggers. Rather, it seeks to highlight some of the challenges and complexities that should factor into the decision-making process. Fully functional and competitive markets may prove superior to even the most sophisticated autoregulation when the goal is to achieve efficiency-based policy objectives. The more multi-faceted a policy's purpose is, however, the more likely regulatory automation is to produce more balanced results than markets alone. In these instances, selective use of market metrics to trigger regulatory adjustment without handing the reigns over to the market's invisible hand may be the better policy choice.

IV. AUTOMATED REGULATION AND ALGORITHMIC GOVERNANCE

From credit scoring to advertising campaigns, from human resources to medical diagnostics, artificial intelligence and smart algorithms have become an integral part of our daily lives and the global economy.[240] The public sector, too, is increasingly relying on algorithms to assist with critical functions, such as crime prevention or tax audit selection.[241] Not surprisingly, the proliferation of algorithms has spawned a burgeoning legal literature, raising important concerns about the compatibility of algorithmic decision-making and governance with due process and other constitutional and societal values.[242] Surprisingly, the

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[240] *See, e.g.*, Pauline T. Kim, *Big Data and Artificial Intelligence: New Challenges for Workplace Equality*, 57 U. LOUISVILLE L. REV. 313, 313–14 (2019) (explaining algorithms in the workplace); Joshua A. Kroll et al., *Accountable Algorithms*, 165 U. PA. L. REV. 633, 633, 636 (2017) (discussing algorithmic decision-making in credit card applications); W. Nicholson Price II, *Regulating Black-Box Medicine*, 116 MICH. L. REV. 421, 423 (2017) (exploring the use of algorithms in the medical field); Rory Van Loo, *Rise of the Digital Regulator*, 66 DUKE L.J. 1267, 1281–82 (2017) (reviewing the use of algorithms to facilitate comparison among the offerings on travel websites and other platforms); Mike Kaput, *AI and Advertising: Everything You Need to Know*, MKTG. A.I. INST. (Jan. 8, 2020), https://www.marketingaiinstitute.com/blog/ai-in-advertising [https://perma.cc/LH6B-YGWV] (Dec. 22, 2020).

[241] *See, e.g.*, DAVID ROBINSON ET AL., CIVIL RIGHTS, BIG DATA, AND OUR ALGORITHMIC FUTURE: A SEPTEMBER 2014 REPORT ON SOCIAL JUSTICE AND TECHNOLOGY 18–19 (2014), https://paulohm.com/classes/infopriv15/files/upturn-report.pdf [https://perma.cc/FZ62-CC92]; Elizabeth E. Joh, *Policing by Numbers: Big Data and the Fourth Amendment*, 89 WASH. L. REV. 35, 42–55 (2014) (analyzing algorithmic crime prevention strategies); Kroll et al., *supra* note 240, at 636, 639 (discussing the Internal Revenue Service's use of algorithms to select taxpayers for auditing); *see also* Peter Margulies, *Surveillance by Algorithm: The NSA, Computerized Intelligence Collection, and Human Rights*, 68 FLA. L. REV. 1045, 1057–65 (2016) (explaining the use of algorithms to gather intelligence in the fight against the Islamic State of Iraq and Syria).

[242] *See, e.g.*, Jane Bambauer & Tal Zarsky, *The Algorithm Game*, 94 NOTRE DAME L. REV. 1, 22–33 (2018); Emily Berman, *A Government of Laws and Not of Machines*, 98 B.U. L. REV. 1277, 1309–31 (2018); Robert Brauneis & Ellen P. Goodman, *Algorithmic Transparency for the Smart City*, 20 YALE J.L. & TECH. 103, 118–32 (2018); Citron, *supra* note 9, at 1278–1301; Citron & Pasquale, *supra* note 9, at 10–18; Cary Coglianese & David Lehr, *Improving the Administrative State with*

scholarly community has yet to make the connection between algorithmic governance and its forebear, automated regulation. This Part aims to close that gap by elucidating the intriguing relationship between regulatory automation and algorithmic governance. Both have, after all, a lot to learn from one another.

In terms of mathematical sophistication and technical complexity, deep-learning algorithms are lightyears ahead of the algebraic formulae that underlie most regulatory automation. Policy-makers would be well advised, therefore, to draw on the predictive power of algorithms as they craft the next generation of self-adjusting regulations.[243] For all its mathematical simplicity, automated regulation boasts something that algorithmic governance misses dearly—a track record covering more than a century's worth of practical experience. As the public sector continues to expand its reliance on artificial intelligence and increasingly seeks to employ algorithms—not only in an advisory capacity but also for adjudicative purposes—policy-makers would do well to consider valuable lessons learned over the last hundred years of regulatory automation.[244]

A. The Theory: Algebra Meets Calculus

The term "algorithm" generally denotes the series of mathematical steps that enable machine learning, commonly understood as the automated process of discovering relationships and patterns among different variables in a dataset, usually with the objective of making predictions about future outcomes.[245] Whatever the mathematical nuances that distinguish different algorithms, they all operate through the optimization, i.e., maximization or minimization, of an objective function.[246] In a recent article, David Lehr and Paul Ohm break down the algorithmic process into eight distinct steps.[247]

The first step requires a clear definition of the problem or question to be solved, such as the goal of predicting a job candidate's performance if hired,

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Machine Learning, 42 ADMIN. & REGUL. L. NEWS 7, 8–9 (2017); Coglianese & Lehr, *supra* note 9, at 38–50; Mariano-Florentino Cuéllar, *A Simpler World? On Pruning Risks and Harvesting Fruits in an Orchard of Whispering Algorithms*, 51 U.C. DAVIS L. REV. 27, 35–41 (2017); Deven R. Desai & Joshua A. Kroll, *Trust but Verify: A Guide to Algorithms and the Law*, 31 HARV. J.L. & TECH. 1, 6–23 (2017); Kim, *supra* note 240, at 323–27; Kroll et al., *supra* note 240, at 678–82; McKenzie Raub, *Bots, Bias and Big Data: Artificial Intelligence, Algorithmic Bias and Disparate Impact Liability in Hiring Practices*, 71 ARK. L. REV. 529, 544–58 (2018).

[243] *See* discussion *infra* Part IV.A.

[244] *See* discussion *infra* Part IV.B.

[245] *See, e.g.*, KEVIN P. MURPHY, MACHINE LEARNING: A PROBABILISTIC PERSPECTIVE 1–2 (2012).

[246] Most common is the use of a loss function that seeks to minimize the disparities between observed response variable values and fitted response variables as inputs. *See, e.g.*, RICHARD A. BERK, STATISTICAL LEARNING FROM A REGRESSION PERSPECTIVE 35 (2008).

[247] *See* David Lehr & Paul Ohm, *Playing with the Data: What Legal Scholars Should Learn About Machine Learning*, 51 U.C. DAVIS L. REV. 653, 670 (2017).

and the output variable that best represents job performance.[248] Next, the data for the multitude of input variables and the outcome variable must be collected, through gathering of existing and/or measuring of new data.[249] In our example, relevant data could be demographic, educational, and other information about past hires along with their performance on the job, as measured by promotions, salary raises, complaints, and similar indicators. The third step involves cleaning of the assembled dataset, such as by filling in missing values and correcting for false values.[250] An employee's age showing as four-years-old, for example, would warrant correction, or possibly elimination, of such data from the set. Next comes a summary statistics review that probes into the values that a given variable takes on and weeds out outliers.[251] Step five involves partitioning data into a first set for training the algorithm and a second set used to test the algorithm's performance on new data.[252] Only now is the stage set for selection, or programming, of the actual algorithm, choosing from a variety of classes, such as "random forests models" or "neural network" models, distinguished by the approach taken to optimize the objective function into which the starting problem has been translated.[253] Once the algorithm has been selected, it is trained using the partitioned data set accompanied by tweaks, known as tuning, iterative assessment of training runs, and feature selection.[254] Finally, after the previous seven steps have been successfully completed, the algorithm is ready to be deployed and to start making predictions for use in the real world,[255] such as forecasting the job performance of a pool of applicants.

The dazzling complexity of smart algorithms with their multivariate calculus and iterative learning processes stands in stark contrast to the relative simplicity of most automated regulation. Fuel adjustment clauses, for example, rely on little more than middle-school algebra to deliver self-executing adjustments to electricity rates. Rate case proceedings generally start with the utility company's overall revenue requirement (R), commonly denoted by the straightforward formula of $R = r \times B + O$, where B represents the utility's rate-based assets, r denotes the allowed rate of return or cost of capital, and O

[248] *See id.* at 672–77.
[249] *See id.* at 677–81.
[250] *See id.* at 681–83.
[251] *See id.* at 683–84.
[252] *See id.* at 683–88.
[253] *See id.* at 688–95 (listing the specific technical criteria guiding the choice of algorithm).
[254] *See id.* at 695–701.
[255] *See id.* at 701–02.

stands for the utility's operating expenses.[256] Thus, the fuel inputs that determine the fuel adjustment clause's operation simply modify one variable in this formula upward or downward.

In the context of clean energy incentives, automated regulation follows a similarly straightforward approach, connecting an independent variable (for example, deployment) to a dependent variable (incentive level), that is subject to potential adjustment.[257] The relationship between both can be described as follows: If deployment is lower than X, the incentive level goes up by a pre-specified increment. If deployment is higher than Y, the incentive level ramps down by a pre-specified increment. Finally, if deployment is higher than X but lower than Y, the incentive level stays constant.

Replacing the passage of time with a market-related independent variable, such as deployment, marked an important first step toward more realistic automated adjustments to changes in the cost of emerging technologies, and, hence, the appropriate level of public policy support. Imagine the possibilities if, for the next generation of automated regulation, policy-makers turned to machine learning and smart algorithms to deliver self-executing adjustments. Instead of a single time- or market-based independent variable, an algorithm could incorporate the full spectrum of variables that combine to determine the cost of production for a given technology. In the case of electricity from solar photovoltaic installations, for example, these variables would include the price of panels, inverters, racks, and other hardware, as well as the cost of capital, permitting, labor, and other soft-cost factors.[258] A well-trained algorithm could use these variables to not only track cost developments, but, importantly, produce more accurate forecasts to inform clean energy incentive levels going forward.

Upgrading today's crop of automated regulation with the predictive powers of smart algorithms would enable policy-makers to take a more proactive approach to shaping the energy economy of the future. This algorithmic crystal ball may come at a cost, however, as it would infuse regulatory automation with the same concerns about transparency, bias, and other issues that have spawned such a rich legal literature on algorithmic decision-making.[259] If the widespread scholarly skepticism toward algorithmic governance and machine learning is any indication of future litigation, then policy-makers will want to

[256] For a more detailed discussion of the utility's revenue requirement and its allocation to volumetric rates, see JOEL B. EISEN ET AL., ENERGY, ECONOMICS, AND THE ENVIRONMENT: CASES AND MATERIALS 481–84 (5th ed. 2019).

[257] *See supra* notes 114–117 and accompanying text.

[258] *See supra* note 120 and accompanying text.

[259] *See supra* note 242 and accompanying text.

carefully weigh, on a case-by-case basis, the relative costs and benefits of adding artificial intelligence to the automated regulation toolkit.[260]

B. The Practice: Advisor Meets Adjudicator

Algorithms have become ubiquitous, if not necessarily salient, companions in our daily lives. The private sector relies on their predictive prowess across a wide range of contexts.[261] The legal literature has long followed—and criticized—the use of algorithms in credit scoring and reviewing loan applications.[262] Algorithmic assessments of job candidates and their employability have garnered similar attention.[263] Dating websites have long relied on algorithms to suggest potential partners to their users.[264] The use of big data and algorithms is revolutionizing medical diagnostics and the delivery of health care.[265] The much-anticipated arrival of self-driving cars depends on machine learning and smart algorithms to process the multitude of data required to ensure the safety of all traffic participants.[266] Today, no profession appears immune to the charm of machine learning. Already, "virtual attorneys" are looking to replace flesh-and-blood lawyers.[267] Not even the clergy is safe, with experts predicting that a variety of services historically performed by priests could soon be provided by algorithms.[268]

With such daunting prospects, it comes as no surprise that interest in machine learning is soaring. In the U.S. financial sector alone, investment in smart algorithms and other forms of artificial intelligence tripled to more than

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[260] *See* discussion *supra* Part III (exploring the costs and benefits of regulatory automation more generally).

[261] *See supra* note 240 and accompanying text.

[262] *See, e.g.*, Bambauer & Zarsky, *supra* note 242, at 19–20; Citron & Pasquale, *supra* note 9, at 8–10.

[263] *See, e.g.*, Kim, *supra* note 240, at 313–14; Raub, *supra* note 242, at 529–30.

[264] *See* Anupam Chander, *The Racist Algorithm?*, 115 MICH. L. REV. 1023, 1024 (2017).

[265] *See, e.g.*, Roger Allan Ford & W. Nicholson Price II, *Privacy and Accountability in Black-Box Medicine*, 23 MICH. TELECOMMS. & TECH. L. REV. 1, 7 (2016); Price, *supra* note 240, at 425.

[266] *See, e.g.*, Bryant Walker Smith, *Proximity-Driven Liability*, 102 GEO. L.J. 1777, 1779, 1792–93 (2014) (discussing the proliferation of algorithms and other technology as a catalyst for autonomous vehicles).

[267] *See* Karni Chagal-Feferkorn, *The Reasonable Algorithm*, 2018 U. ILL. J.L. TECH. & POL'Y 111, 113; Anthony Sills, *ROSS and Watson Tackle the Law*, IBM WATSON BLOG (Jan. 14, 2016), https://www.ibm.com/blogs/watson/2016/01/ross-and-watson-tackle-the-law [https://perma.cc/SAX2-ZMYS]; *Watson Takes the Stand*, THE ATLANTIC (IBM SPONSORED CONTENT), http://www.theatlantic.com/sponsored/ibm-transformation-of-business/watson-takes-the-stand/283 [https://perma.cc/T8DA-2QHG].

[268] *See* Chagal-Feferkorn, *supra* note 267, at 113; Richard Susskind & Daniel Susskind, *Technology Will Replace Many Doctors, Lawyers, and Other Professionals*, HARV. BUS. REV. (Oct. 11, 2016), https://hbr.org/2016/10/robots-will-replace-doctors-lawyers-and-other-professionals [https://perma.cc/RGH7-8X34] (forecasting that many traditional professions will be dismantled within decades).

twelve billion dollars between 2013 and 2014.[269] In a 2017 report, PriceWaterhouseCoopers estimated that artificial intelligence technologies could boost global GDP by more than fifteen trillion dollars, or nearly fifteen percent by 2030.[270]

For all their past success and future promise in the private sector, artificial intelligence and smart algorithms have so far led a more subdued existence in the public sector. That is not to say that algorithms do not play any role at all.[271] But contrary to the claims of some commentators, algorithms do not (yet) regulate our lives.[272] Rather than replacing human decision-making as has occurred in many private contexts, algorithms generally serve to inform and assist human actors with administrative decision-making.[273]

In the smart city movement, for example, machine learning helps municipal governments make sense of the vast data—from transportation to energy consumption to education—used to inform the next generation of urban design.[274] What consequences to draw from the data and how to translate insights into policy action, however, remain the prerogative of human decision-makers. Similarly, algorithmic intelligence has been used to direct food safety inspectors to establishments that are likely to violate applicable standards but makes no prescription as to the imposition of fines or other penalties.[275] In a fiscal context, federal agencies rely on algorithmic review of tax returns to select taxpayers for auditing.[276] The actual review of the tax return in question and

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[269] *See* Nathaniel Popper, *The Robots Are Coming for Wall Street*, N.Y. TIMES MAG., Feb. 28, 2016, at 56, https://www.nytimes.com/2016/02/28/magazine/the-robots-are-coming-for-wall-street.html [https://perma.cc/27FB-SWDH].

[270] PWC, SIZING THE PRIZE: WHAT'S THE REAL VALUE OF AI FOR YOUR BUSINESS AND HOW CAN YOU CAPITALISE? 4 (2017), https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf [https://perma.cc/B7BT-F2D8].

[271] *See supra* note 241 and accompanying text.

[272] *But see* Lilian Edwards & Michael Veale, *Slave to the Algorithm: Why a 'Right to an Explanation' Is Probably Not the Remedy You Are Looking for*, 16 DUKE L. & TECH. REV. 18, 19 (2018) ("[A]lgorithms regulate our lives.").

[273] *See* Coglianese & Lehr, *supra* note 9, at 7 ("Today, most governmental applications of machine learning are not determinative of final actions."). For a survey and critique of the growing use of artificial intelligence by government agencies to provide low-cost advice to citizens, see Joshua D. Blank & Leigh Osofsky, *Automated Legal Guidance*, 106 CORNELL L. REV. (forthcoming 2021) (manuscript at 4–9), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3546889 [https://perma.cc/H2GQ-T7XV].

[274] *See* Brauneis & Goodman, *supra* note 242, at 114.

[275] *See* Mohana Ravindranath, *In Chicago, Food Inspectors Are Guided by Big Data*, WASH. POST (Sept. 28, 2014), https://www.washingtonpost.com/business/on-it/in-chicago-food-inspectors-are-guided-by-big-data/2014/09/27/96be8c68-44e0-11e4-b47c-f5889e061e5f_story.html [https://perma.cc/BB9N-DBJ6].

[276] *See* JANE MARTIN & RICK STEPHENSON, INTERNAL REVENUE SERV., RISK-BASED COLLECTION MODEL DEVELOPMENT AND TESTING 141–42 (2005), https://www.irs.gov/pub/irs-soi/05stephenson.pdf [https://perma.cc/R6YS-YWDT].

any determination of tax evasion or fraud, however, is the responsibility of a human Internal Revenue Service official. The legal literature has already engaged with the proliferation of predictive policing practices that use big data and algorithmic intelligence to inform police patrol routes, seeking to leverage historical crime data to prevent future crime.[277] The National Security Agency, too, has embraced machine learning as an important reconnaissance tool in the fight against terrorism.[278] Courts, meanwhile, are using algorithms to assess the risk of recidivism at sentencing.[279]

A common feature across all of the above government applications of algorithmic intelligence[280] is that machine learning is used to inform, but *not* replace, human decision-making. Make no mistake, even limited to an advisory capacity, algorithms are having an impact on public policy and regulation.[281] Still, as a general matter, algorithms do not exercise adjudicatory functions. It appears to be only a matter of time, however, for government to employ algorithms in more outcome-determinative ways.[282] Recent scholarship cautions that more widespread adoption of algorithms and other forms of artificial intelligence by agencies, who often fail to understand their inner workings, calls into question the judicial deference that agency expertise traditionally commands.[283] Expanding government use of (poorly understood) artificial intelligence offers striking parallels to the widespread reliance of agencies on pri-

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[277] *See, e.g.*, Andrew Guthrie Ferguson, *Policing Predictive Policing*, 94 WASH. U. L. REV. 1109, 1123–44 (2017); Joh, *supra* note 241, at 42–55.

[278] *See* Margulies, *supra* note 241, at 1057–65.

[279] *See, e.g.*, State v. Loomis, 881 N.W.2d 749, 754, 774 (Wis. 2016).

[280] The above offers but a snapshot of the many applications of algorithms by governments. Other equally advisory uses include the administration of social security benefits, bail determinations in criminal proceedings, as well as immigration matters and travel restrictions. *See* Chagal-Feferkorn, *supra* note 267, at 113; Citron, *supra* note 9, at 1252. For further instances of algorithmic applications, see Coglianese & Lehr, *supra* note 9, at 7–8; Darrell M. West & John R. Allen, *How Artifical Intelligence Is Transforming the World*, BROOKINGS (Apr. 24, 2018), https://www.brookings.edu/research/how-artificial-intelligence-is-transforming-the-world/ [https://perma.cc/X2EW-TJDA].

[281] *Natural Resources Defense Council v. United States Environmental Protection Agency*, a recent U.S. Court of Appeals for the Second Circuit decision, illustrates the crucial role that even advisory models and algorithms play for policy-making. 954 F.3d 150, 152 (2d Cir. 2020). Following the Environmental Protection Agency's decision to freeze greenhouse gas emission standards for new motor vehicles, environmental advocacy organizations filed suit under the Freedom of Information Act to gain access to the model used to justify the agency's rulemaking—a different model than the one used in prior rulemaking efforts on the same topic. *See id.*

[282] *See* Coglianese & Lehr, *supra* note 9, at 8; *see also* DAVID FREEMAN ENGSTROM ET AL., GOVERNMENT BY ALGORITHM: ARTIFICIAL INTELLIGENCE IN FEDERAL ADMINISTRATIVE AGENCIES 15–21 (2020), https://www-cdn.law.stanford.edu/wp-content/uploads/2020/02/ACUS-AI-Report.pdf [https://perma.cc/RMZ8-6MKX] (reviewing federal agencies' use of algorithms).

[283] *See* Calo & Citron, *supra* note 167, at 22–24, 36 (presenting compelling evidence of state and federal agencies' use of algorithms and other forms of artificial intelligence about which such agencies have limited understanding).

vate, self-regulatory organizations, including the well-documented problems of excessive deference to their quasi-governmental actions.[284]

In the early days of the Internet, Monroe Price described the governmental response to technology innovation as an attempt "to divine how the newness of information technology affects the porousness of boundaries, capacities of old institutions to regulate new realities."[285] In the context of regulatory automation by algorithm and other forms of artificial intelligence, government is in the fortunate position to answer these critical questions with a more educated guess than usual. As we inch closer toward true algorithmic governance, traditional forms of automated regulation can offer critical guidance to courts, agencies, and policy-makers.

For more than a century, state and federal agencies have made adjudicatory use of self-adjusting regulations, as illustrated by the case studies surveyed in Part II. Fuel adjustment clauses have allowed public utility commissions to set rates for electricity and gas, while similar adjustment mechanisms continue to determine the value of public policy incentives for emerging clean energy technologies—all without the need for human involvement.[286] Such dehumanized governance has been met with skepticism and elicited administrative as well as judicial challenges, not to mention considerable pushback from the scholarly community. The resulting battles have produced important insights, including best and worst practices. As policy-makers seek to assign more outcome-determinative adjudicatory roles to smart algorithms and other forms of artificial intelligence, they should consider these insights and practices, always mindful of the fundamental differences between algorithmic and algebraic forms of automated governance.

CONCLUSION

Shakespeare's Hamlet was neither the first nor the last to grapple with "the law's delay."[287] At some point or another, we have all shared the Prince of Denmark's frustration with lengthy regulatory proceedings getting in the way of timely responses to pressing policy issues. For more than a century, regula-

[284] *See* Emily Hammond, *Double Deference in Administrative Law*, 116 COLUM. L. REV. 1705, 1711 (2016) (warning that "combining . . . judicial deference with the oversight agency's deference obscures the many participatory, deliberative, and transparency-related shortcomings of the overall scheme"). On judicial deference to agency decisions generally, see Chevron, U.S.A., Inc. v. Nat. Res. Def. Council, Inc., 467 U.S. 837, 842–44, 866 (1984).

[285] Monroe E. Price, *The Newness of New Technology*, 22 CARDOZO L. REV. 1885, 1886 (2001).

[286] *See* discussion *supra* Parts II.B., III.B.

[287] *Re* Lynchburg Gas Co., 6 P.U.R.3d 33, 35 (Va. State Corp. Comm'n), *additional opinion sub nom. Re* Va. Elec. & Power Co., 7 P.U.R.3d 108 (Va. State Corp. Comm'n 1954), *aff'd sub nom.* City of Norfolk v. Va. Elec. & Power Co., 90 S.E.2d 140 (Va. 1955).

tory automation has offered an alternative, more expeditious path forward through self-executing adjustments that keep regulations up to date and effective amidst changing circumstances. The benefits of such autopilot-regulations, however, extend well beyond mitigating the negative consequences of regulatory inertia.

At a time of congressional deadlock, political partisanship, and growing polarization, automated regulation's ability to accommodate a wide range of competing beliefs and assumptions about the future can serve as a catalyst for more consensual policy-making. Public choice theory suggests that the resulting innate diversity of potential outcomes makes regulatory automation a natural antidote to the frequently observed domination of special interests in the policy-making process.

Importantly, automated regulation has already received widespread judicial approval and can produce these and other benefits in the here and now. The greater mathematical sophistication of deep-learning algorithms and other forms of artificial intelligence might improve the accuracy of self-executing regulatory adjustments. But policy-makers should weigh the resulting benefits against the costs associated with upgrading from automated to algorithmic governance. Widespread concern over the implications of artificially intelligent regulation for privacy, due process, and other constitutional discontents may well tip the scales in favor of more simplistic yet well-established forms of automated regulation, powered by basic algebra instead of multivariate calculus.

Regulatory automation is no panacea. There will always be areas where ethical concerns and value judgments, among other factors, require human decision-making. Selective use of automated regulation can promote these processes by enabling policy-makers to focus their efforts on those more delicate domains most deserving of their personal attention.